DARK TEXT IN THE BOOK

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- International Organization and Conference Series
  - General
  - Regional
    - American Republics
    - European and British Commonwealth
    - Far Eastern
    - Near and Middle Eastern and African
  - United Nations (including Commissions)
  - Specialized Agencies
    - (See Chart of the United Nations)

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INTRODUCTION

The extensive development of radio and electronic aids to navigation during the war has made it necessary that consideration be given to standardizing to the highest practicable degree the methods and equipment used in this internationally important field. To this end it is desirable that representatives of all interested nations be well informed on all types of navigational aids and that there be occasional opportunities to review these devices in the light of further experience. The International Meeting on Marine Radio Aids to Navigation (IMMRAN), held at New York City and New London, Connecticut, April 28–May 9, 1947, was for the purpose of demonstrating United States progress in this field, with the hope that it would produce conclusions and resolutions leading to world standardization of radio aids which could be recorded for reference and utilization at future international conferences considering standardization of equipment in this field.

The first international meeting of this kind was the International Meeting on Radio Aids to Marine Navigation (IMRAMN), held by the British Government in May 1946. The United States IMMRAN followed approximately a year later and was similar in many respects to the British meeting.

The United States IMMRAN agenda was divided into three parts: The first part was devoted to lectures and exhibits setting forth the merits of the various systems manufactured in the United States and covering basic problems of navigation in which radar and position fixing systems are designed to help. This part of the Meeting was conducted at the Roosevelt Hotel in New York City, which was chosen because of its convenient location and accessibility to the various companies and laboratories exhibiting equipment. For the lectures, the United States called on outstanding authorities from government, industry, and universities to present papers on the various aspects of radio aids to marine navigation. These were all delivered during the session in New York. In addition to the papers presented by the United States, an opportunity was given foreign delegates to present papers, and papers were presented by delegates from the United Kingdom, France, and Denmark.

The second part of the Meeting was devoted to actual shipboard demonstrations of those United States systems considered to be sufficiently developed and operationally tested to warrant their consideration for possible standardization. This part of the Meeting was held in the vicinity of New London, Connecticut, which was chosen because of its favorable location for conducting the demonstrations in question. For the shipboard demonstrations, the United States Maritime Commission

training ship *American Sailor*, the United States Coast Guard Cutter *Campbell*, and the United States Coast and Geodetic Survey ship *Lydonia* were used. The *American Sailor* had five radar equipments aboard (each of which represented the product of a different United States Manufacturer) and also had two radiotelephone equipments aboard (A.T.&T and Mackay). The *Campbell* was used primarily for demonstrating Loran equipment, and the *Lydonia* was used primarily for demonstrating Shoran, Fathometers, and associated hydrographic survey equipment. In addition to the government ships the Sperry Gyroscope Company very kindly made their laboratory vessel *Wanderer* available to assist in the demonstrations of radar and Loran.

The third and last part of the Meeting was devoted to discussions of the material presented in the first two parts and for recording any conclusions, recommendations, or views which resulted therefrom. This part of the Meeting was held at the United States Coast Guard Academy at New London, Connecticut.

Assistant Secretary of State Garrison Norton was Honorary Chairman of the Meeting; Dr. William L. Everitt, Head of the Electrical Engineering Department of the University of Illinois, was Chairman of the Meeting and presided at all the plenary sessions; Captain John S. Cross, of the Telecommunications Division of the Department of State, was Executive Secretary of the Meeting; and Lieutenant Commander L. E. Brunner, United States Coast Guard, was the Program Coordinator.

As originally planned, it was not believed necessary to have any special committees for the Meeting. Near the end of the first week, however, it became evident that there would be need for some international committees to reconcile any differences of opinion and draft any recommendations and conclusions that appeared appropriate. Accordingly, the Chairman of the Meeting appointed a Steering Committee consisting of representatives from eleven countries. This Steering Committee in turn appointed three subcommittees as follows: Committee A—Radar; Committee B—Medium and Long Distance Aids (other than radar); and Committee C—Consideration of all aspects of radio aids to navigation not covered by Committee A and B above. The conclusions, recommendations, and views drafted by these three committees were presented to the plenary session for discussion, comment, and adoption and are contained in Chapter V.

It is considered that this Meeting accomplished its aims effectively, i.e., it informed the delegates from other countries of the United States policy in this field; it demonstrated the progress which the United States has made in the development of marine radio aids to navigation; it informed the delegates regarding adoption of new raido aids to navigation by the United States Government; it informed the delegates regarding the availability, type, and quality of marine radio navigational aid equipment produced by United States manufacturers; and it produced a number of conclusions, recommendations, and views which should be very helpful for use both domestically and internationally at future meetings or conferences on this subject.

It is also considered that the Meeting has been particularly effective in assuring the nations of the world that the United States, from the viewpoint of both government and industry, is keenly alive to the requirements of the mariner for radio aids to navigation and is presently operating effective systems which are practicable and proven and which can be expanded on a world-wide basis.

Since it was not the object of the Meeting to negotiate any binding agreements, the delegates did not have plenipotentiary powers, and, therefore, no formal agreements were signed. However, it is believed that the work accomplished at this meeting resulted in a more sympathetic attitude on the part of the delegates towards the establishment of standards for international systems of radio aids to navigation. Accordingly, such work will stand as an effective signpost for similar future meetings, at which it is hoped agreement may be obtained for the adoption of standard world-wide systems of raido aids to navigation which will effectively meet the needs of the mariner.

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ANNEX A

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PART ONE

General

CHAPTER I

INTRODUCTORY AND OPENING ADDRESSES

MORNING SESSION, MONDAY, APRIL 28, 1947

Mr. JOHN S. CROSS, the Executive Secretary of the International Meeting on Marine Radio Aids to Navigation (IMMRAN), introduced the Honorable GARRISON NORTON, the Assistant Secretary of State of the United States and Honorary Chairman of IMMRAN, who delivered the following official opening and welcoming address:

Secretary NORTON: Gentlemen, it gives me great pleasure officially to open this International Meeting on Marine Radio Aids to Navigation and to welcome you here today on behalf of the United States Government.

As in London last May, the representatives of the nations here present have been drawn from both the administrative and the technical sides of this important field. You have assembled here to view and discuss the various marine radio aid equipments and the many improvements which United States technicians have developed, and to compare these devices with those you saw at the meeting sponsored by our British colleagues last year.

You are aware that wartime developments advanced the technical knowledge and use of radio aids to an almost incredible degree. As a consequence, there are now available to us radio navigation devices of proved merit which a few years ago were either unknown or merely in early stages of discussion by those responsible for their creation. The fact that such devices are now available places the nations of the world in a position to select those which prove to be the best.

At this meeting it will, of course, be the aim of the United States delegates to demonstrate to their colleagues from other countries the progress which our country has made in the development of marine radio aids to navigation. In this connection we shall show you many of the newest devices adopted by the United States Government and we shall also inform you as to the availability, type, and quality of marine radio aid equipments produced by United States manufacturers. However, I believe I speak for all of us when I express the hope that our discussions and inspections at this Meeting will serve only to accelerate our thinking and to focus our selective eye upon the right material and techniques, regardless of their place of origin.

At this meeting it will also be the aim of the United States to keep delegates of the other nations informed as to our policy in this field. The United States believes that some standardization of marine radio aids is essential if we are to preserve spectrum space, avoid unnecessary expenditure of funds, and eliminate duplication. If as a result of the Meeting it should appear that conclusions and resolutions leading to some degree of world standardization can be worked out by the nations represented here, we shall have taken a long step in the right direction. We shall have taken such a step, however, only if we center our attention upon the very best equipments and techniques the art affords.

There is one point that I should like to make crystal clear to those who are concerned with agreeing upon which aids should be standardized and what the standards should be: The United States Government is opposed to any standardization which would result in monopolistic or exclusive advantages to one country as against another. We have previously voiced this principle in connection with standardization of radio aids to air navigation and I should like to quote you the statement of our spokesman at a recent meeting of the Provisional International Civil Aviation Organization in Montreal:

> "If equipment or devices developed, patented, or manufactured by the United States Government or its nationals are established as global standards by PICAO, the United States Government will use its best offices to ensure full freedom of manufacture of such equipment or devices by any Member State. The United States will not advocate or accept any standard which would entail any monopolistic or exclusive advantage to any one country or to any one business enterprise or group of enterprises."

At that Meeting, our British colleagues made a similar statement as follows:

> "The United Kingdom will not be party to the world standardization of any equipment of British design and manufacture unless provision can be made for the production of this equipment in other appropriately qualified countries desiring to manufacture it. The Government of the United Kingdom will do everything in its power to render necessary technical information and specifications available to such countries on favorable and convenient terms."

We believe that this principle should also apply to marine radio navigational aids and, if adopted by the other nations of the world, would permit you administrators, engineers, and scientists to select the best techniques and equipment and to standardize

where you believe standardization is desirable. Accordingly, I submit for your consideration the matter of adopting such a principle by formal resolution at this Meeting.

In order that you gentlemen have as complete a discussion as possible, the United States has invited visiting delegates to present papers at this Meeting. Together with those presented by representatives of the United States, these papers will bring you up to date on developments that have transpired in this field since the London Meeting. You will see that the United States has called upon representatives from both Government and Industry of this country to participate in this Meeting. They are authorities in their respective fields, and I am confident that their talks will go a long way to further the purposes for which we are assembled here.

As Chairman of this Meeting the United States has selected Dr. WILLIAM L. EVERITT, who is well informed in the field of radio navigation. He is not directly connected with either Government or Industry. This gentleman is well known to most of you, and I am sure you will agree that we can rely upon him so to conduct these meetings that the views of each nation will be adequately presented. Dr. EVERITT is Head of the Electrical Engineering Department of the University of Illinois. He is a Past President of the Institute of Radio Engineers, an organization which, I am sure, is well known to all of you. During the war he was Director of the Operational Research Staff of the Chief Signal Officer of the United States Army. In this position he enjoyed an unusual opportunity to become acquainted with the operation and performance of the various radio aids to navigation utilized by the Allied Forces. Dr. EVERITT's operational experience, together with his fine technical background and understanding of the requirements for such a meeting as this, qualify him to an exceptional degree, in our opinion, for the chairmanship of this Meeting. I am confident that as the Meeting progresses and those of you who do not already know Dr. EVERITT become acquainted with him, you will agree that our choice was a wise one.

It is, of course, the international aspect of this Meeting that is of primary concern to the Department of State of the United States Government. That is why the Department has sponsored this Meeting and why, in the absence of Secretary MARSHALL, I am welcoming you today on behalf of our Government. The Department is intensely interested in the success of this Meeting. Although we are not scientists or technicians we are acutely aware of the importance of radio navigational aids in the postwar development of a peaceful and prosperous world. We have been active in the formulation of our policy and in the preparations for this meeting. We have assigned Captain JOHN S. CROSS of our Telecommunications Division

as the Executive Secretary. His job is to see that each delegate becomes well informed as to our developments in this field. I know he will welcome any requests or suggestions you may have in this regard.

Since we hope to show you how the United States is actually meeting, or proposes to meet, her marine navigation problems, we believe it highly appropriate that the man who will coordinate the demonstrations of equipment and techniques is an officer of the United States Coast Guard. The merchant shipping of this country looks to the Coast Guard as the service of this Government charged with providing safeguards for the mariner. Our Program Coordinator is, therefore, Lieutenant Commander L. E. BRUNNER, of the United States Coast Guard Headquarters in Washington, D. C.

So, gentlemen, I declare this Meeting officially open. Again I welcome you here as our guests. I hope your Meeting will be a successful one and to that end I urge your active participation. I now turn the Meeting over to your Chairman, Dr. EVERITT.

Dr. WILLIAM L. EVERITT: Thank you, Mr. NORTON. Ladies and Gentlemen, I am indeed honored by the privilege of serving as presiding chairman at a meeting of so many distinguished persons.

It is interesting to observe that the earliest applications of electricity were to the problems of communication. The communication engineer and scientist has ever been generally interested in extending man's senses. First he gave us the privilege of talking over greater distances, and more recently he has not only extended the senses of speech and hearing but also the sense of vision so we can see greater distances. In earlier applications it has been necessary to have at the source of the information some device which would collect the intelligence and transform it into electrical form to be transmitted. More recently we have been able to send out radio waves looking for information and, when they have found it, they are able to return to us and bring us a message which can then be presented in a form easy for interpretation.

I think we also recognize that marine applications have received the greatest benefactions from radio, the first important applications being to the extension of safety of life and property at sea.

In gathering in this Meeting to consider the various problems of marine radio aids to navigation, I think we may be happy that we have so many means to choose from. Only a few short years ago we would have welcomed even a single solution, whereas today we are not seeking a solution but we are choosing among many solutions.

In this position I think that we, however, should not be in the position of a child in a candy shop who is presented with so many

wonderful things that he is, on the one hand, not able to choose between them or, on the other hand, he selects so many that he is afflicted by indigestion. We are here primarily to observe, discuss, and collaborate on the various solutions that have been presented.

At the onset Mr. NORTON, the Honorary Chairman, has given assurances that should remove any concern regarding manufacturing advantages that might accrue through standardization on any particular solution, and, should it be possible to keep this in mind throughout the meeting, our concern need only be to include those operational and technical aspects that will provide the most reliable, useful, convenient, and safe radio aids to marine navigation.

If you will bear with me briefly I should like to outline some of the procedures for conducting our lecture sessions. At this initial meeting, when we were gathering and registering, we found that we started a little bit later than the scheduled time. I am going to insist, though, that the future meetings shall start promptly on time. Beginning with the afternoon session you can count on the fact that the gavel will come down at the scheduled time in your program.

In general the lectures will consume from 15 to 20 minutes, and we will have a short 5- or 10-minute question-and-answer period thereafter and questions from the floor will be welcome. We will, however, keep each speaker and the question-and-answer period to the time that is assigned. Therefore, you will find in many cases that the time allowed is not as long for discussion as you would wish. When questions from the floor arise I will either answer the question or refer it to the speaker or to one of our technical advisers, or, if it is quite comprehensive and requires extended discussion, we will place it on the agenda for the final discussion period which will be held at New London on Thursday of next week. Many of you may find after the close of the lecture that further points or questions arise in your mind and you would like to have them clarified. If so, I would like to have you submit them to me or to one of our assistants, Lieutenants GRAHAM, OLSON, and DOMKE. You may wish to identify these gentlemen as the liaison officers in the organization of the Secretariat, which is shown on your program. Their names appear in the lower left-hand corner, and you may wish to underline them. You should submit to them such questions as you wish to be placed on the agenda for the final discussion next week.

We also have on the Secretariat Lieutenant COWIE. His specific duty is to provide any of the members of the meeting with further information on the subjects discussed, and he will help you obtain further reference material. You will also find that the manufacturers will be delighted to make available to you any printed

material that they have, and Lieutenant COWIE can help you get in touch with them or you can contact them in the booths of the various demonstrations that we have in the outer rooms.

I am well aware that many of you were unable to bring with you all of your technicians and engineers and scientists who would like to participate in this meeting and hear the discussions. Therefore, we have attempted to provide sufficient copies of the papers to permit you to take some home with you, and the manufacturers will also make available printed material that they may have. Some of the electrical engineering students in the United States who have come here from their home countries to study have had contact with the United States Coast Guard and have obtained material from them. Some of them may not know that this is available, and we would be glad to have them contact the Coast Guard in the future. I believe a number of them are attending these meetings as observers. We are delighted to have them and they are most welcome.

We also recognize that some of you may have difficulty in following the speakers, due to the use of technical terms in English, and to assist you in this respect we are arranging to have copies of each lecture placed upon your table immediately before it takes place. The speaker, of course, may not follow it word-for-word, but the essential points will be there indicated.

I am not going to engage in a long summary but prefer to open our meeting immediately for general discussion. However, it has been indicated that Sir ROBERT WATSON-WATT would like to respond for the delegates at this time. I will call on Sir ROBERT.

Sir ROBERT WATSON-WATT (UK): Mr. Assistant Secretary of State, Mr. Chairman, I have been accorded the very great privilege and pleasure of speaking as the voice of the visiting delegates in thanking you for the invitation which you have extended to us and for the very charming words of welcome you have addressed to us.

You, Mr. Assistant Secretary, have spoken in the name of Mr. Secretary MARSHALL and I am sure that my fellow delegates would join me in asking that you should take our own special greetings to Mr. Secretary MARSHALL on his return from arduous duties overseas to duties scarcely less arduous in his own country. We are grateful for his welcome.

We thank you for extending to us this further opportunity of seeing, hearing, and speaking about the beneficent applications of radio techniques to the pursuits of peace. We welcome particularly your references to the desirability of doing nothing in this International Meeting which should tend to inhibit the still very rapid progress which is being made both technically and operationally in

in the applications of the classical and the newer radio aids. We shall associate ourselves, and we shall welcome the opportunity of very formally associating ourselves with the assurances which we were happy to give in the corresponding aviation gathering on the efforts which our governments will make to insure the freest availability of technical information to facilitate manufacture and application in the very diverse and diversely qualified countries which we have the honor to represent.

We are saying thank you at the beginning of the proceedings, confident that we shall thank you with even greater zeal at the end.

For the moment we have only one complaint. We think that you would have done well in the arrangements which you have made to speak to Mr. REICHELDERFER about the visibility conditions outside. We find it something of a hardship that you should have made it so difficult for us to immure ourselves even within these pleasant walls. We appreciate the kindness of the weather which you have provided for us, but a little dimming of the sky outside the shop windows might make it easier to carry out our duties.

If I might seize this opportunity to speak personally to you I would speak alike as an individual and as a representative delegate in saying how pleased we are to have the opportunity of sitting under your chairmanship. You and I, sir, have had a long association in the applications of radio aids to various things, and if I may abuse my privileged position I would like to say that I, personally, very gratefully welcome this opportunity of sitting under your chairmanship. After all, I have some right to speak personally. I am a commuter on the trans-Atlantic ferry and I feel myself nearly as much at home in this new country as in my own, and so I plead that excuse for taking this opportunity of speaking to you as an individual and to our cousins generally on behalf of all the delegates here assembled on saying thank you.

The Chairman presented Mr. JOHN S. CROSS, Assistant Chief of the Telecommunications Division of the Department of State, who was also serving as the Chairman of the United States Delegation and Executive Secretary of IMMRAN.

Mr. CROSS (US): Mr. Chairman, distinguished guests, I shall divide my remarks into two categories—those pertaining to my participation as the Executive Secretary of IMMRAN and those pertaining to my participation as a part of the United States Delegation. However, I hasten to add that the combination of these remarks will be brief, since I subscribe heartily to the doctrine that the head can understand only so much as the seat can endure.

In both of the official capacities I should like to echo the welcome which has already been expressed by Secretary NORTON and

Dr. EVERITT. We are indeed pleased to have such a representative group here with us.

The Executive Secretary of a meeting of this kind is, under the Chairman, responsible for the general planning, coordination, and management of the meeting and acts, therefore, somewhat as a major-domo. The general planning for this meeting has been a group activity of government and industry, and I should like to take this opportunity to thank publicly the advisory program group for the fine planning job it has done and the administrative group for its excellent execution of these plans.

My government extended invitations to this meeting to all countries with which it maintains diplomatic relations and has taken great pains to bring many of its own technical experts in the field of marine radio aids to navigation to this meeting. The program also provides opportunity for our colleagues from other countries to express their ideas. I am therefore confident that our program will be both interesting and informative. However, in addition to these factors, we also wish to insure that your stay with us will be a pleasant one, so don't hesitate to call upon me or any of the officers of the Conference for assistance, as we all stand ready to help in any way we can.

Now, speaking as Chairman of the United States Delegation, I should like to tell you a little something about the United States policy in the field of radio aids to navigation. When the United States Delegation came back from the London IMRAMN meeting last year, they considered that it was important for the United States to develop a policy in this field. Accordingly, a committee was formed, under the chairmanship of Admiral O'NEILL, of the United States Coast Guard for this purpose. This committee had representation from all the interested government agencies of the United States and, after considerable study of the problems, it arrived at a recommended policy. The recommended policy was adopted by the Department of State and is now the recognized policy of this government for radio and electronic aids for marine navigation. This policy has been documented as a part of the meeting and will be available to all the delegations. In order that you may all be informed in this regard, I ask your indulgence while I read it to you. (Mr. CROSS then read IMMRAN Document No. 5, entitled "United States Policy for Radio and Electronic Aids for Marine Navigation", which is included in full in Part II of this volume.)

Some of you know and are known by the members of the United States Delegation. However, in closing I should like to state that the United States Delegation hopes that it will get to know all of you gentlemen individually; that you in turn will get to know us; and that, in our day-to-day discussions of our problems in this field,

we will find solutions which will be mutually acceptable to all of us; and that the end result will be a successful meeting for all concerned.

Lieutenant Commander L. E. BRUNNER, United States Coast Guard, the Program Coordinator of IMMRAN, briefly outlined program arrangements, after which the morning session ended.

CHAPTER II

NEW YORK SESSIONS; DELIVERY AND DISCUSSIONS OF TECHNICAL PAPERS

AFTERNOON SESSION, MONDAY, APRIL 28, 1947

The Chairman presented Professor H. L. SEWARD (US), who delivered IMMRAN Document No. 6, "World Radio Aids to Navigation". This paper presented a short summary of events leading to the United States IMMRAN, including a review of recent developments in the field of international radio aids to marine navigation. The trade routes of the world were outlined along with some estimates as to the needs for radio navigational aids on the routes. A philosophy of aids to navigation was developed and some of the pertinent characteristics of a lasting aid were pointed out.

Mr. E. K. JETT (US) presented IMMRAN Document No. 7, "Frequency Bands and Their Utilization for Marine Radio Aids to Navigation". This paper offered a broad and objective outline of the frequency service-allocations being proposed by the United States to the International Telecommunications Conference for the maritime navigational service. Joint use of facilities by marine and aviation services, where practicable, was advocated. Salient features of systems and equipments to be utilized in the proposed navigational bands were touched on, and the necessity for world agreement on the standardization of navigational systems and appropriate frequency service-allocations was stressed.

Rear Admiral EARL E. STONE (US) gave IMMRAN Document No. 8, "The Selection and Conversion of War Developed Electronic Systems for Peacetime Use". This paper presented general comments concerning aids to marine navigation and the suitability of various systems for peacetime use. The importance of standardizing electronic aids to navigation was stressed; inviting particular attention to the consideration of frequency assignments at the then-approaching International Telecommunications Conference. The radio and electronic aids specifically mentioned were Radar, Shoran, Loran, Medium-frequency Direction Finders, Radio and Radar Beacons, and VHF Radio Communications. Recommendations were also set forth as to requirements for navigational aids in areas (a) less than 3 miles from land, (b) between 3 and 50 miles from land, and (c) over 50 miles from land.

As there was no further discussion of any of the papers presented, the Meeting adjourned.

MORNING SESSION, TUESDAY, APRIL 29, 1947

The first paper, IMMRAN Document No. 9, "The User's Viewpoint on Radio Navigational Systems for Ocean Going Vessels", was presented by Mr. EDWARD C. PHILLIPS (US). This paper discussed in an overall manner the viewpoint of the commercial shipowner with respect to the various electronic navigational devices that have been made available, or potentially available, to him in recent years. The factors which he must take into consideration with respect to these new devices were pointed out. The paper explained the dilemma with which the shipowner will continue to be confronted until such time as definite international agreements are arrived at which will enable him to make use of these new devices throughout the world.

In presenting the next speaker, the Chairman invited the attention of the meeting to the methods of "operational research" by which the data for Mr. JANSKY's paper were obtained. Noting that "operational research" consists of more than merely turning an equipment over to a user and asking his opinion of it but is actually a coordinated study of problems by manufacturer and user, the Chairman stated his belief that operational research would be useful in many other problems.

Mr. C. M. JANSKY, Jr. (US) then presented IMMRAN Document No. 10, "The Application of Marine Radar to Lake, River, and Passage Navigation". This paper described briefly the Great Lakes Radar Operational Research Project carried out during 1946 under the auspices of Lake Carriers Association. Lake, river, and passage navigation were found to require radar which will serve three functions, namely (1) collision prevention, (2) position finding in open waters, and (3) navigation combined with collision prevention in confined waters. The requirements for all-purpose navigational radar capable of serving all three functions are set forth as they were developed for the Great Lakes with comment regarding the similarity of these requirements for open water, river, passage, and harbor navigation elsewhere.

Mr. KNOX McILWAIN (US) stated that, in his experience with radar in aircraft, considerable difficulty was had with clouds. He asked if similar difficulty with cloud return on marine radars was experienced when the range was cut down to 4 or 5 miles.

Mr. JANSKY replied that no such difficulty had been experienced.

Mr. J. H. ROWLATT (Canada) said that the 40-mile range that Mr. JANSKY recommended for navigational radars appeared to be based on anomalous propagation and asked what Mr. JANSKY considered the maximum range to be under such conditions.

Mr. JANSKY (US) replied that the principal value of a range of 40 miles was primarily to show a sufficient portion of the coast line to enable its identification.

Mr. MANSFIELD (US) presented IMMRAN Document No. 11, "Radio Navigational Aids for Small Craft" in somewhat condensed form. A non-technical analysis of certain existing marine radio navigational devices and systems was given, together with their present and prospective possibilities and limitations as applied to the needs of small craft. A division was drawn between pleasure boats and small commercial vessels in considering their respective requirements for these navigational aids. Specific problems encountered by the vessel owners, research engineers, and equipment manufacturers were discussed.

Rear Admiral TELFAIR KNIGHT (US) presented IMMRAN Document No. 12, "U. S. Maritime Commission Electronic Training Program". This paper stressed the importance of training in the comparatively new field of electronics in the merchant marine. It outlined the electronics training in navigation given by the United States Maritime Commission to (1) Cadet-midshipmen at the United States Merchant Marine Academy at Kings Point, New York, (2) Merchant Marine Officers at USMS Service Schools at New York and San Francisco, and (3) Radio Officers at the USMS Training Station at Sheepshead Bay. General outlines of the scope of each of these courses were given as a preparation for the visits to some of these schools by the IMMRAN delegates.

Mr. WILLIAM ROSS (UK) compared Rear Admiral KNIGHT's description of the fairly lengthy course of Loran instruction, in which the dangers of superficial knowledge were emphasized, with Mr. MANSFIELD's statement that a navigator could be trained in the use of Loran in one day, and asked if this divergence of views could be clarified.

Lieutenant Commander G. C. FONDA (US) explained that the two views were actually not contradictory, as Mr. MANSFIELD had reference to the use of Loran on small craft which do not venture great distances to sea and are always within ground wave range of Loran stations where Loran operation is very simple. The longer period of training described by Rear Admiral KNIGHT is necessary to give transocean navigators the required experience in the use of skywaves.

Rear Admiral KNIGHT (US) added that the Navy's wartime experience indicated that 4 or 5 days of intensive study were necessary for personnel to master the subject completely.

Mr. LORANCHET (France) asked if any reports on the efficiency of the radar maintenance men who had completed the 8-weeks course were available.

Commodore McLINTOCK (US) replied that some reports had just been received but had not yet been analyzed.

Rear Admiral KNIGHT (US) said that the men trained in radar maintenance had had previous training in communication equipment maintenance and therefore he believed them satisfactorily trained.

Mr. DAVID (France) asked for an explanation of why the accuracy of Loran fixes vary in accuracy from a few hundred yards to several miles and if the reliability of a given fix could be interpreted by the operator.

Lieutenant Commander FONDA (US) explained that this was due in part to the geometry of any hyperbolic system.

The Chairman said that a fuller answer to the question would be given by Dr. BARROW's paper the following day.

Captain AKSIC (Yugoslavia) asked if the United States Maritime Commission Training Schools were open to foreigners.

Rear Admiral KNIGHT (US) stated that under present legislation the schools were restricted to citizens of the United States. He added that he would be most happy to receive foreigners in the schools if legislation permitted.

In reply to questions from Lieutenant SOUBASSAKOS (Greece), Rear Admiral KNIGHT explained that the men trained in radar and electronics maintenance had previously completed a 9-month course in radio operation and maintenance. They were required to have a first class operator's license and to have served under that license a minimum of 16 months before being admitted to the 8-week course in radar and electronics maintenance.

AFTERNOON SESSION, TUESDAY, APRIL 29, 1947

Captain R. W. RAVENHILL (UK) presented IMMRAN Document No. 13, (U. K. Paper No. 3), "A Review of the Navigational Requirements and the Radio Navigational Systems Available—Views of the U. K. Delegation". This paper presented a comprehensive picture of United Kingdom opinion for all classes of navigational aids and concluded that a combination of Radar, Decca, and Consol would satisfactorily meet the requirements of the mariner. This paper was a sequel to a similar paper presented at the London IMRAMN by the speaker, being an enlargement of the first paper and bringing the United Kingdom views up to date.

Captain RAVENHILL (UK) then showed a slide of the figure appearing in IMMRAN Document No. 39 (U. K. Paper No. 4), "An Examination of

the Oceans of the World in Relation to the Requirements for Radio Navigational Aids". The speaker explained this part briefly, pointing out that it was presented merely to give a conception of the coverage which would result from the integrated Radar-Decca-Consol combination recommended by the United Kingdom if adopted internationally.

In reply to questions by Commodore McLINTOCK (US) concerning Decca, Captain RAVENHILL (UK) requested that he be allowed to leave these questions unanswered until after presentation of the Decca paper.

In reply to another question by Commodore McLINTOCK (US), the speaker stated he did not believe it would be economical to provide a long range aid especially for the mariner but, since such aids were necessary for aircraft, it would seem desirable that they be sited with a view toward marine interests. In this manner, the mariner would be provided with an aid which could be described as most useful but possibly not essential.

Commodore McLINTOCK (US) then asked the United Kingdom position in regard to the large existing radiobeacon system.

Mr. HORTON (UK) stated that the attitude of the United Kingdom on the matter was that MF/DF does not quite reach the accuracy that the navigator has agreed to be required for his purpose. To achieve that accuracy over large areas merely by MF/DF would require a prohibitively large number of stations. While recognizing the great service that these stations have provided in the past, the United Kingdom feels that we are now in possession of better methods of position fixing on which we should concentrate in the future. The existing MF/DF stations should continue to be used, but additional money and effort should not be expended in their improvement and extension.

Captain RAVENHILL (UK) added that the plotting of D/F bearings on Mercator charts is a nuisance, and that without the use of special-projection charts inaccuracies were introduced in the plotting as the distance from the station increased.

Commodore McLINTOCK (US) asked if a position can be determined from Consol only, without the use of a direction finder or any supplementary means of finding the approximate DR position.

Mr. HORTON (UK) stated that the ambiguity of a Consol line was on the order of 20 degrees but that for maritime use it had been assumed that this is no disadvantage. Within the Consol system itself, however, there is no means of resolving this ambiguity.

Captain HARDING (US) asked if the speaker could state the range and accuracy figures upon which the comparisons of the systems discussed in the two papers were based.

Captain RAVENHILL (UK) replied that, broadly speaking, the figures were those found in the proceedings of the London IMRAMN. He said that it was difficult to go into all the details of each system.

Mr. MINNERS (US) asked if some idea could be given of the cost of a dual system of Consol and Decca in terms of frequencies.

Mr. STANESBY (UK) said that the feeling was that Consol might occupy a band of 10, or perhaps 15 or 20, kilocycles, depending upon how extensively the system was used. The Decca system would require a band of approximately 8.5 kilocycles.

Mr. BLAISDELL (US) asked what were defined as "coastal waters" in terms of radius; i.e., would coastal waters be 50 miles, 100 miles, or 20 miles.

Captain RAVENHILL (UK) answered that at the original meeting an effort was made to produce a table for the scientists in order to give them an idea of the type of aid that is required. He admitted that such a table could be picked full of holes and that he did not believe that the navigators were at all keen to produce any table stating precise distances, etc. However, the definition of "coastal area" as given in his paper was anything between 3 and 50 miles from the nearest danger. In further discussion of the accuracy of direction-finders, Captain RAVENHILL stated that the MF/DF did not give the required accuracy throughout the coastal area. Its accuracy varies from four to sixteen times the stated accuracy of a quarter of a mile required in this region.

Mr. BLAISDELL (US) stated that his reason for bringing up the matter was that on the Great Lakes direction finders had been used until the advent of radar and that the coverages of 3 to 50 miles were quite accurately covered by direction finders in manufacture.

Captain RAVENHILL (UK) stated that he doubted that they were under all conditions covered with the required accuracy. He agreed that special localities would undoubtedly be best suited by special aids. He recalled the case of a large liner running ashore on the Portland Bill, due to an undetected error in a D/F bearing, and stated that the inaccuracy of D/F can lead to trouble.

Lieutenant Commander McNALLY (US) commented that we are agreed that it is possible to make a radar which has sufficient accuracy and resolution combined with a chart comparison unit to give one a pinpoint location in pilotage waters. In fact, this has been achieved. Yet we find some reluctance on the part of the skipper to advance his ship up those restricted waters under conditions of total invisibility to his eye. He feels that radar cannot anticipate. It merely presents an instantaneous record. In spite of the fact that

he has very valuable data as regards speed and location and that it is possible mechanically to transfer to the chart a point of light that moves along as his ship moves up the channel, the seaman's eye would notice the little change in the tide as the bow starts to swing or change in the wind, or the little garbage lighter setting out from the beach, and other hazards, plus the ever present danger of failure of the apparatus in the middle of a very hazardous transit, for which the only alternative would be to drop the hook. Lieutenant Commander McNALLY solicited the views of the speaker on this problem.

Captain RAVENHILL (UK) replied that, without a doubt, where the waters are restricted beyond a certain point no electronic device could get one into the harbor. On the other hand, there are many harbors where one might take a ship out purely on radar, this depending in part upon the class of ship. To do this, the master must be indoctrinated in the use of radar and have confidence in it. That this confidence is being gained is evidenced by the fact that some masters are doing things they would never have dreamed of before having radar. He quoted a case of quite a large ship entering Capetown on radar without seeing anything until the two sides of the breakwater were abreast of the ship. However, this incident he believed unduly daring. He felt that great savings of time could be made with radar in the larger harbors under conditions when the visibility is on the order of a quarter of a mile.

Lieutenant Commander McNALLY (US) asked if the use of radar might not promote the element of daring and thereby penalize users for accidents they might have when using radar and, in addition, penalize radar in the minds of the users and the insurance companies.

Captain RAVENHILL (UK) replied that he hoped this would not happen and did not believe it would. One must recognize an aid to navigation not as an "end-all" but must realize its limitations and use it intelligently.

The Chairman next presented Commander W. B. BERNARD (US), who delivered IMMRAN Document No. 14, "Considerations Affecting a Choice of Radar Operating Frequencies". This paper presented briefly the considerations of radio propagation and required angular definition, which govern the choice of the frequency for navigational radar, with the emphasis on frequencies of 3,000 mc/s and 9,000 mc/s. It was noted that these considerations, in turn, are influenced by the conditions under which a ship is to operate. The lower frequency was favored for cases where it is most desirable that a reliable maximum range be obtained, and the higher frequency was favored where high angular resolution with a small antenna is deemed the most important factor.

With reference to certain of the attenuation figures in Commander BERNARD's paper, Mr. STANESBY (UK) stated that his figures on a 3-cm radar attenuation indicated that a reduction in range from about 10 to 5 miles resulted from a rate of precipitation of about 50 mm. He felt that the discrepancy might be due to the fact that Commander BERNARD's calculations assumed that d-to-the-4th-power law applied, whereas he believed d-to-the-8th-power law to be more appropriate for a target at a range of 10 miles during precipitation. Noting that both his own and Commander BERNARD's calculations assumed a constant precipitation over the entire path, he admitted that this was unlikely, since the 50 mm. per hour figure quoted occurs only about twelve times per year, for periods of 6 minutes each, in the regions of most dense rainfall, and in England only once a year for a period of 6 minutes. Which simply means that by using 9,000 mc/s a better picture is obtained the greater part of the time, since the angular resolution is increased by a factor of 3 over 3,000 mc/s radar and the amount of time that precipitation would seriously impair 9,000 mc/s operation is negligible. With regard to back-scattering, Mr. STANESBY said that their reports have indicated that this does not present any great difficulty.

Commander BERNARD (US) agreed that the resolution of the 9,000 mc/s radar would be greatly superior for a given antenna size but said that he did believe the d-to-the-4th-power law to be valid for 10 miles with a normal antenna height and a target the size and height of a ship. He added that precipitation at the rate of 20 mm. per hour occurs an appreciably greater percentage of the time than the 50 mm. rain referred to by Mr. STANESBY. He indicated that back-scattering was experienced under extremely heavy precipitation and rough seas. He felt that the decision as to whether or not to sacrifice resolution the small percentage of the time when these adverse conditions prevail was a matter for the individual operator.

Commander O. C. ROHNKE (US) gave IMMRAN Document No. 15, "U. S. Anti-Collision and Navigational Radars". This paper presented an outline of the action taken to produce a set of marine radar specifications which are now in use in the United States. A review was given of the commercial radar equipments which were to be demonstrated during IMMRAN, with comments regarding the general use of a shipboard radar.

Lieutenant SOUBASSAKOS (Greece) referred to the speaker's statement concerning the difficulties of identifying low-lying land masses and suggested that radar reflectors might solve that problem without the use of any other aids.

Commander ROHNKE (US) replied that advantage should be taken of all the aids available, i.e., radiobeacons, fathometer, etc.

Sir ROBERT WATSON-WATT (UK) asked if the data obtained on the International Ice Patrol concerning the use of radar in relation to the pick-up ranges of actual ice had been tabulated and could be made available to the delegates to the meeting.

Lieutenant Commander BRUNNER (US) replied that the data had been tabulated but had not yet been published. He felt sure that it could be obtained by a direct request to the Coast Guard.

Lieutenant Commander G. L. OTTINGER (US) presented IMMRAN Document No. 16, "Utilization of Radar Beacons and Reflectors", illustrated with slides. In this paper the corner reflector, the Ramark, and the responder beacon were discussed with regard to their construction, applications, and limitations. It was noted that the mariner finds it practicable to navigate safely in most cases with his radar and the usual less glamorous tools without special radar aids.

Mr. ROSS (UK) asked to what extent commercial United States radars made provision for receiving radar beacons outside the main radar band.

Lieutenant Commander OTTINGER (US) replied that regular beacons for marine service had not been installed because the manufacturers had not provided for their reception; however, they had been asked to make some provision for some sort of modification to enable the radars to receive outside the main band. He stated, however, that the modification to enable such reception was comparatively simple and he felt sure that the United States manufacturers could meet the demand which might arise for such modifications. He added that the reception of beacons on commercial radars would be included in the New London demonstrations.

Mr. ROSS (UK) asked what would be the United States opinion of radar beacons operating on the principle of sweeping in frequency through the main radar frequency in order to avoid the necessity for a special modification to the radar receiver.

Lieutenant Commander OTTINGER (US) said that such a plan has many merits. He felt that in the best interests of the safety of life and property at sea it was better to have a satisfactory beacon operating outside the main radar frequency than to take a chance on obtaining interference from a "walking beacon" of the type to which Mr. ROSS referred. It had been noted with the Ramark and responder beacons that there was a definite amount of additional clutter on the scope when these were in operation. While the United Kingdom may have developed such a beacon to the point that it gave no serious interference, the United States had no experience in that respect and preferred to play safe until shown.

Commander RYZHKOV (USSR) asked if any tests were being conducted to determine the applicability of corner reflectors to topographic and survey work.

Lieutenant Commander OTTINGER (US) said that one manufacturer had been using corner reflectors for very precise topographic surveying and that there were undoubtedly other applications of which he was not aware. In cases where there is low-lying land, he believed that the corner reflector would provide very good results.

Sir ROBERT WATSON-WATT (UK) stated that the detection of small fishing vessels by radar presented a difficult problem to large ships travelling through the areas in which these fishing boats operate. He suggested that the Meeting might do well to consider and discuss some form of passive radar reflector which might be mounted on the masthead of small vessels to enable their detection by radar and suggested that this subject be added to the agenda.

Lieutenant Commander OTTINGER (US) agreed that this was a problem of considerable importance. A number of masters have remarked that they can see the lights of a small fishing fleet 10 miles away but often cannot pick it up on the radar until they are considerably closer. The Coast Guard, in its experiments with small collapsible corner reflectors on lifeboats, had found them very unsatisfactory, as they were unreliable and not much better targets than the boats themselves. While it is reasonable that some form of corner reflector would materially assist in the detection of small boats, its form must be carefully worked out.

Lieutenant Commander McNALLY (US) asked the United Kingdom delegation if they had tried putting a corner reflector on small craft and rotating it with a means of giving some identification to the corner reflector. While the collapsible reflector is unsatisfactory because it is a flimsy affair without the requisite intersecting planes, the United States Navy has had limited success with small, rotatable corner reflectors.

Commander PARMINTER (UK) said that such a system had been used very successfully by the Dover Command exactly as described for the detection of their own motor torpedo boats. He was not aware that it had been recently elaborated or pushed any further.

MORNING SESSION, WEDNESDAY, APRIL 30, 1947

The first paper of the morning session, IMMRAN Document No. 17, "Modern Depth Finders", was presented by Dr. R. L. STEINBERGER (US). This paper, which the speaker condensed somewhat in its delivery, reviewed the art of depth finding, beginning with a brief history

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and ending with a description of several late-model instruments. The physical principles underlying the operation of modern depth finders were separated, classified, and briefly explained. The manner in which these principles are integrated into complete systems was indicated.

Captain RAVENHILL (UK) asked if the United States Navy had obtained satisfactory results with recording echo sounders at speeds in excess of 20 knots.

Dr. STEINBERGER (US) replied that, in general they behaved satisfactorily. He stated that the important consideration was the mounting of the transducer. It must be far enough aft so as not to pick up bubbles or undue turbulence, and the hull must be kept clear of protuberances and the resulting cavitation over the face of the transducer.

Mr. LORANCHET (France) asked if the United States had any experiences or reports of the use of echo depth finding in the fishing industry.

Dr. STEINBERGER (US) replied that he had no direct experience in the matter but that the fishermen seemed to be gratified with their results.

Mr. BLAISDELL (US) added that the depth finder allows the fishermen to remain on a particular ledge or bank and make their catch over a good feeding ground. Also, an indication is obtained on the depth finder when the vessel passes over a school of fish. Since most of the fishermen in this country are in business for themselves or working on shares, anything which allows them to save time, fuel, and money in making their catch is considered by them to be a good investment.

Lieutenant Commander C. N. DANIEL (US) next presented IMMRAN Document No. 18, "U. S. Marine Radiobeacons". This paper outlined the development of the system of United States Marine Radiobeacons and covered the operational aspects of the system since its inception. The relationship of component phases which, combined, form an integrated radio aids to navigation system was discussed.

Captain HARDING (US), referring to the ten continuous wave beacons mentioned in Lieutenant Commander DANIEL's paper, added that these did not supply a continuous wave only. The continuous wave feature is for the use of automatic direction finders, but the signal also has superimposed on it a 75% modulated signal which can be used by direction finders unable to receive continuous wave transmissions. Therefore this type of beacon does not deprive existing direction finders of any service whatever.

Sir ROBERT WATSON-WATT (UK) pointed out that in some of their papers the United Kingdom had expressed their concern over the comparative inaccuracies of the direction finders served by shore-based radiobeacons. He felt it desirable that an understanding be reached as to the relative importances attached to these various inaccuracies by the United States and the United Kingdom. Amplifying Mr. HORTON's remarks of the previous day (see page 16), he stated that the United Kingdom regarded the ship-based direction finder a rapidly obsolescent device and thus the shore installation of beacons to serve it an interim and decaying service. Anticipating that the radiobeacon and its associated direction finder will disappear within a period of roughly 10 to 20 years, the United Kingdom would be reluctant to go into any large scale extension of its present direction finding facilities. Recognizing that these facilities will be required to render service for a period of 10 or more years, the United Kingdom will continue to maintain them and even cautiously and conservatively work off a portion of its prewar installation program. He added that there still remained the important distress and sea rescue aspect of the direction finding problem, which required special treatment and would doubtless be discussed later in the meeting.

Lieutenant Commander DANIEL (US) replied that he hesitated to predict the future of the radiobeacon. He believed that it had proved very satisfactory and would probably continue for some time to come, especially in the United States, because of the amount of coastal traffic and small craft which might not be able to afford a more elaborate device.

Captain HARDING (US) invited the attention of the United Kingdom delegation to the description of the United States radiobeacon system given in the front of the light lists. This, in effect, reveals the experience of 20-odd years of the United States with radiobeacons and summarizes the United States position with regard to them, especially as regards night effect. He added that the discussion of the matter by Dr. SMITH-ROSE given on page 11 of Volume II of the London IMRAMN documents is fully subscribed to by most United States people who have had experience with radiobeacons.

Mr. H. BUSIGNIES (US) presented IMMRAN Document No. 19, "New Developments in Marine Radio Direction Finders". This paper reviewed the past and present state of marine radio direction finding and compared its merits and fields of application with those of radar and loran. It was noted that marine direction finders, while they have incorporated all the design and component progress made in radio in the last 20 years, are still not only working on the same basic principle but the means of achieving measurements are practically the same as 20 years ago. Some of the reasons for this and the factors which appear to limit future progress were reviewed.

A number of suggestions for improvement were presented, with discussions of their practicability. A short motion picture on high frequency direction finders was shown in connection with this paper.

Mr. WILLIAM ROSS (UK) presented a digest version of IMMRAN Document No. 20 (U. K. Paper No. 15), "The Decca Navigator". This paper briefly described the principles of the Decca system and discussed the progress made during the past year in the technical developments and performance of the system. The lane identification feature was described and a summary of the operational experience of the past year presented.

Mr. VERSTELLE (Netherlands) asked if it is possible to reach a higher accuracy for survey work by the use of shorter wave lengths.

Mr. ROSS (UK) replied that he did not believe this possible because of the greater effects of reflections on the higher frequencies.

Commodore McLINTOCK (US) asked if there were any practical operational data on the reliability of Decca under conditions of high noise level and if there were any operational research studies of Radar and Decca, side-by-side, in pilotage waters.

Mr. ROSS (UK) replied that very little information was available on the performance of Decca under high noise conditions, since the system had been used only in the vicinity of the United Kingdom where the noise is relatively low. He added that since the bandwidths of the Decca channels were very narrow and that it was intended ultimately to use channel widths of only 100 to 200 cycles per second, the effects of high noise conditions should be thereby lessened. He indicated that the side-by-side studies of radar and Decca had been made and that the opinion was that the two aids are complementary.

Mr. STANESBY (UK) added that in the matter of reliability he had been unable to detect any response from the Decca meters when the ship's communication transmitters were operated, even on 500 kilocycles. He described an experience in the English Channel during an extremely severe storm, during which conditions were so bad that they were unable to communicate with a shore station only 7 miles away. During this storm it was noted that the Decca meter would flick only about 1/20 of a lane when lightning struck the sea close to the ship.

AFTERNOON SESSION, WEDNESDAY, APRIL 30, 1947

The afternoon session opened with the presentation of IMMRAN Document No. 21, "Pulse Navigation Systems", in somewhat condensed form,

by Dr. W. L. BARROW (US). A variety of navigational systems based on pulsed radio transmission developed during and since World War II were reviewed, together with a discussion of the most significant scientific and engineering factors that influence the suitability of such systems for practical adoption.

Mr. ROSS (UK) asked, since separation of ground and sky waves is impossible in L.F. Loran, if its performance would not be similar to that of Consol, where this separation is likewise impossible. Also, he had seen it suggested that correction for the systematic error due to skywave might be possible in L.F. Loran and wondered if correction might not be equally possible in the case of Consol. He solicited the United States opinion on these points.

Dr. BARROW (US) replied that he did not know the official United States position but that his personal impressions were that errors could occur due to skywaves and that the experiments to date had not been sufficiently definitive to clarify the points in question.

Mr. CROSS (US) stated that L.F. Loran was not yet a part of the United States policy and that the United States was not prepared to make any statements concerning it beyond the fact that experiments were in progress and the system appeared to have promise.

Mr. C. E. HORTON (UK) presented a digest version of IMMRAN Document No. 22 (U. K. Paper No. 6), "3-cm Shipborne Radar Progress in the U.K. since the First IMRAMN". This paper, which made reference to other U. K. papers (notably numbers 7, 8, 9, and 10; IMMRAN Documents No. 46, 47, 48, and 49, respectively) briefly summarized the United Kingdom progress in shipborne radar since the first IMRAMN. The United Kingdom performance specifications, type-testing arrangements, operational trials, and recent developments were discussed.

Lieutenant SOUBASSAKOS (Greece) asked, with regard to radar charts, if it would not be possible to overlay standard navigational charts with transparent sheets on which would be printed the significant radar navigational aspects of a particular area.

Captain RAVENHILL (UK) replied that he believed that the distortions due to humidity and temperature would be different for the two sheets and would render this approach impractical. He believed, however, that by further experimentation it would be possible to produce charts equally suitable for radar and general navigation by accenting prominent radar responsive features, etc.

Mr. DAVIDSON (Canada) inquired if the United Kingdom had under development an over-all monitoring system that included the antenna and waveguide.

Mr. HORTON (UK) replied that experimental work was in progress but the results were not yet conclusive. The monitor system was based on the idea of receiving a part of the energy which goes out from the aerial in an echo box, converting it to a higher frequency, transforming that higher frequency into a supersonic isolation, and using a crystal delay line to delay retransfer back to the receiver by a sufficient interval of time to make it quite clear on the screen.

Mr. DAVIDSON (Canada) then asked if the United Kingdom was considering any government service of inspection of radar equipment on ships, analogous to that now used for wireless.

Sir ROBERT WATSON-WATT (UK) replied that the United Kingdom was considering a maintenance system which would run in conjunction with the post office. He could not give any details, since they were not yet in a position to inspect their existing commercial practice, but he expected there would certainly be a comprehensive system on this matter.

Commodore H. MANNING (US) delivered IMMRAN Document No. 23, "Standard Loran in the Merchant Marine". In this paper some of the practical factors affecting successful use of Loran as an aid to navigation were discussed. The need for additional Loran coverage in the approaches to the British Isles was stressed, and the importance of training in the use of this, as well as other electronic aids, was emphasized.

Commander PARMINTER (UK) asked if the ships of the United States Merchant Marine carried sufficient officers for them to have time to give close attention to all the new aids to navigation as well as to their other duties.

Commodore MANNING (US) replied that if the officers did not have this time they must find it.

Mr. LORANCHET (France) questioned Commodore MANNING (US) concerning his experience with radar, with particular reference to cluttering, aboard the S. S. AMERICA.

Commodore MANNING (US) replied that at the moment he found the clutter, or sea return, the principal shortcoming of his 10-cm. radar. He did not wish to engage in controversy over the relative merits of 3- and 10-cm. equipment, since he had used only the 10-cm. He did believe, however, that by close observation an experienced operator could detect the differences between real and false echoes the major portion of the time and thus use the radar effectively. Since there are times when the radar will not be effective under these conditions, to accept the radar as infallible is not

prudent. He found the effects of rain and squalls to be less objectionable than those of heavy sea return.

Lieutenant Commander McNALLY (US) asked if the speaker had found the radar to perform reliably over extended periods of time without maintenance and servicing.

Commodore MANNING (US) replied that maintenance difficulties aboard the AMERICA had been very slight. If the instrument is properly serviced when the vessel comes to port, it may be used without hesitation for days on end.

Sir ROBERT WATSON-WATT (UK) asked concerning the speaker's experience in picking up ice and wooden ships by radar.

Commodore MANNING (US) said that his sea routes were such that he had not encountered ice. With regard to wooden vessels, he was convinced that even the smaller ones can be picked up in time to avoid collision, if the radar scope is watched closely.

The next speaker, Captain LAWRENCE M. HARDING (US), presented IMMRAN Document No. 24, "Practical Progress in Loran for Marine Navigation". This paper briefly summarized some of the practical experience in providing Loran service and in actual operational use of Loran by merchant ships and civil aircraft since the London IMRAMN. A report of simple methods used to alleviate or eliminate interference to other radio services in or adjacent to Loran frequency channels and a summary of technical characteristics of new and improved postwar Loran ground station equipment were presented. Estimates of the costs of operation of new postwar Loran stations in terms of men, money, and frequency band were given, and new operational experiences in the use of Loran by small craft, by ocean aircraft, and for purposes of medium distance navigation were described.

Mr. ROSS (UK) commented that it was his impression that an extension of Loran groundwave coverage from the present 700-mile range to 1000 miles would require a power increase on the order of 40 db. He added that the long ranges of standard Loran were dependent upon a clear overwater path, since a very serious reduction in range was caused by intervening land, even stretches of 50 or 100 miles. He invited the speaker's reply.

Captain HARDING (US) replied that he believed the figures given by Mr. ROSS to be approximately correct. The figures mentioned in the paper are very general; the figures given for the daytime service now being obtained generally are being attributed to (1) considerable improvements in the transmitting antennas and transmitting systems of existing stations and (2) the use of rather considerably

improved receivers which give an appreciably better signal-to-noise ratio. The net result of these improvements seem to indicate ranges of 800 miles or better. The 1000-kilowatt transmitters now in construction are expected to give ranges considerably above the present ranges. It is very true that Standard Loran provides the best service over water, and the stations are sited with that in view.

MORNING SESSION, THURSDAY, MAY 1, 1947

The first paper was presented by Commander P. V. COLMAR (US). This paper, IMMRAN Document No. 25, "Improvements in Loran Equipment for Shipboard Use", briefly discussed some of the improvements in Loran equipment since the London IMRAMN. A view of future developments to make use of possible extension of the Standard Loran system was presented.

Mr. ROSS (UK) commented that the envelope of a pulse is propagated with the group velocity of the radio waves, whereas the cycles inside the pulse are cycles of continuous waves and are propagated with phase velocity. In a disturbed medium, such as the ionosphere, these velocities are not the same. In the case of L.F. Loran propagation over long distances, he felt that this factor might preclude the use of cycle matching as an accuracy refinement over envelope matching. He asked if the United States had solved this problem.

Captain HARDING (US) replied that the United States was aware of the problem but could not give an answer at the present time.

Captain RAVENHILL (UK) asked if any difficulties in connection with the power supplies on small vessels were anticipated in view of the recent developments.

Commander COLMAR (US) replied that he did not believe there would be any difficulty on vessels large enough to require a long range navigational aid.

Mr. DAVIS (US) added that the Loran equipments in use embodied electronic voltage regulators and therefore did not require a very stable power supply, being normally able to stand a fluctuation of 10% in source voltage. The total power consumption of the largest equipment is less than 300 watts; the consumption of other sets, even less.

Mr. H. STANESBY (UK) next presented IMMRAN Document No. 26 (U. K. Paper No. 14), "Consol", in somewhat condensed form. This paper briefly described the Consol system and discussed the marine user trials and accuracy investigations since the first IMRAMN.

Commodore McLINTOCK (US) inquired as to the status of the proposed installations of Consol stations in Bermuda and in the Azores.

Sir ROBERT WATSON-WATT (UK) replied that, to the best of his knowledge, there had been no firm decision to install the Consol stations which were recommended in a PICAO Regional Meeting. The matter was to some extent governed by the discussion then scheduled to take place in Montreal within the next few days.

Commander E. K. RHODES (US) presented IMMRAN Document No. 27, "Marine Aids to Navigation Broadcasts". This paper described in detail the methods and facilities used to inform ships at sea of changes in aids to navigation and obstructions to navigation by means of radio broadcasts. The proper manner for shipmasters to report observed obstructions and defects in aids to navigation was outlined.

Captain H. C. MOORE (US) next presented IMMRAN Document No. 28, "Ocean Station Vessel Marine Services". This paper presented a brief discussion of the functions of Ocean Weather Stations, together with an historical resume of the program and the need for the Ocean Weather Stations in the postwar era. A nontechnical discussion of the services rendered by these stations and their use to the maritime world was given.

AFTERNOON SESSION, THURSDAY, MAY 1, 1947

Lieutenant Commander CLARENCE A. BURMISTER (US) delivered IMMRAN Document No. 29, "Electronic Aids for the Control of Hydrographic Surveys". This paper dealt principally with the use of Shoran for hydrographic survey work. The operational techniques involved in the use of this system were discussed in some detail.

Mr. VERSTELLE (Netherlands) inquired concerning the effects of temperature on the accuracy of the ground and ship Shoran stations.

Lieutenant Commander BURMISTER (US) explained that, while the ship stations have no thermal control, the temperature at the ground station is very closely controlled. The ship station is then checked against the ground station about once each hour, thus insuring a high order of accuracy.

Commander PARMINTER (UK) asked for amplification as to the time required to set up a Shoran station ashore.

Lieutenant Commander BURMISTER (US) replied that this varied, depending on whether or not buildings were available, the ruggedness of the terrain, etc. In general, a station could be set up in about 10 hours, provided that the equipment did not have to be packed up steep hills, etc.

Commander PARMINTER (UK) then asked if any use could be made of the system by ships, boats, or attendant small craft, or if it could be used only by the survey vessel itself.

Lieutenant Commander BURMISTER (US) replied that this angle had not yet been fully exploited, as the power requirements are rather high for a small boat. However, his organization planned to install the equipment aboard a 65-foot craft during the coming summer.

In reply to a question by Mr. VERSTELLE (Netherlands), Lieutenant Commander Burmister (US) stated that the distances to the two Shoran ground stations are measured simultaneously.

Commander CASPER M. DURGIN (US) presented IMMRAN Document No. 30, "The Production of Nautical Charts for Radar and Loran". This paper discussed various solutions of modifying the conventional nautical charts to make them useful for navigating with radar and Loran without impairing their usefulness to the navigator whose ship is not equipped with these electronic aids.

Mr. VERSTELLE (Netherlands) commented that he feared that the surveys in a large part of the world were inadequate to permit the drawing of contour lines on land masses for use with radar.

Commander DURGIN (US) agreed and suggested that in such cases it would be best to rely upon a good shore line, since this is the most important feature to be shown.

The Chairman asked if radar itself could be used for survey in such situations to supplement the material on the chart.

Commander DURGIN (US) agreed that it might be possible to use radar to find those special points which respond more strongly than others.

Captain RAVENHILL (UK) asked whether the United States had considered the taking of photographs of the PPI presentation of harbors and issuing these in sailing directions or as inserts on charts.

Commander DURGIN (US) replied that this had been considered but primarily in connection with the preparation of charts. However, at the present time the coast pilots, which correspond to the sailing directions, contain photographs of the shore, and he saw no reason why PPI photographs could not be used for the same purpose.

When asked by the Chairman to elaborate on the United Kingdom's efforts along these lines, Captain RAVENHILL (UK) stated that no definite decisions in the matter had been reached. Whether or not such photographs are desirable is controversial, since any given photograph would apply only for one type of radar and one antenna

height and therefore might be misleading. He added that the United Kingdom had investigated most of the systems discussed by Commander DURGIN. The United Kingdom had done a good deal with tinting and agreed that this offers good possibilities for identifying contours, coast lines, etc. He asked if the United States had done anything in connection with chart comparison units, stating that the United Kingdom was undecided as to the best method of chart comparison.

Lieutenant Commander McNALLY (US) stated that a great amount of work had been done on this problem but that most of the chart comparison units evolved had been too elaborate even for Naval application. He said that the best approach to the problem in this country was a unit very similar to the United Kingdom equipment demonstrated aboard H. M. S. FLEETWOOD at the London IMRAMN and that this model suffers from insufficient light.

Mr. STUART L. BAILEY (US) presented IMMRAN Document No. 31, "Some Examples of the Use of Marine Radiotelephony for Safety Purposes and as an Aid to Navigation". This paper described the application of marine radiotelephony for safety and navigational purposes on the Great Lakes. Illustrations were given of navigational uses for radiotelephony. Operational studies of the application of VHF radiotelephony using frequency modulation as conducted on the Great Lakes were briefly set forth. The paper called attention to the action of the Interim Executive Committee of the Radio Technical Commission for Maritime Services endorsing frequency modulation for use in the 30-to-300 mc. band and the position taken in the United States frequency service allocation proposal respecting the desirability for international standardization upon the frequency 156.81 mc. for the exclusive use of the maritime mobile service for short range communication.

Mr. STANESBY (UK) commented that the thinking in the United Kingdom on this topic had been along lines similar to those expressed by the speaker. The frequencies in the vicinity of 2 mc. are extremely congested in Europe, and it was felt that the higher frequencies would be eminently suitable for short distance communication. The United Kingdom proposed to set aside the band 156 to 162 mc. for short distance communications; therefore there should be no difficulty in arriving at a compromise frequency in this region. Mr. STANESBY observed that shipmasters do not like to have a loudspeaker on in the wheelhouse because of the distractions caused by the conversations between other ships and stations and asked if this difficulty were also experienced in the United States. With regard to the selective ringing systems, he asked if intership calling were done on the selective calling device or on the frequency to which the loudspeaker was tuned.

Mr. BAILEY (US) replied that a squelch circuit was employed to keep the wheelhouse quiet, except when conversations were actually in progress, and that it was mandatory for ships engaging in conversations of any appreciable length to shift to another frequency. As regards the selective ringing, most of the Great Lakes ships have six receivers turned on at all times, and selective ringing takes place on a specific frequency. Selective ringing is employed only on shore-to-ship communications; intership calling is done by voice on the loudspeaker frequency.

Mr. JANSKY (US) added that the matter of having open loudspeakers in the ships' pilothouses had initially been approached with some misgivings. Experience had proved, however, that the ship captains had actually come to welcome this feature, as it enabled them to know what other ship operations were going on in their vicinity without distracting them from their other duties. What had originally been feared to be a disadvantage had turned out to be an advantage.

At this point a number of short movies on various subjects were shown, after which the afternoon session adjourned.

MORNING SESSION, FRIDAY, MAY 2, 1947

The first paper of the morning session, IMMRAN Document No. 32, "Progress in Radio Navigational Aids", was presented by Rear Admiral EARL G. ROSE (US). This paper summarized the important electronic systems of aids to navigation, including the extent to which they are used and the possible and probable future need for these systems.

Captain FENNESSY (UK) made several comments with regard to the section of the speaker's paper devoted to the Decca system. He stated that, while the Decca system was at present providing satisfactory service to ships operating within its coverage area, it was recognized that a lane identification feature was essential, and that this would be provided. The problem of providing this lane identification had been solved and successfully demonstrated on several occasions. There remained only routine engineering problems of integrating the lane identification feature with the operational Decca chains, and it was estimated that this would probably be accomplished by the end of 1947. He indicated that the lane identification feature itself gave positional information accurate to about one-tenth degree at 200 miles.

With regard to Decca coverage, he estimated that approximately eight Decca chains would be required to give coverage of the eastern seaboard of North America from the Gulf of St. Lawrence to the

Gulf of Mexico. He stated that, while the United Kingdom investigations of the system have been limited to ranges of about 300 miles, it was probable that the useful range is considerably in excess of this. He cited examples of its use at ranges of 450, 700, and, in one case, 1500 nautical miles from the center of the system but emphasized that at present no claims for its performance beyond the 300-mile limit could be made and that these figures were quoted merely to illustrate that greater ranges might possibly be realized.

With regard to interference, he stated that the Decca system could normally tolerate interfering signals of an intensity equal to that of the Decca signal. There had, however, been cases in which signals of ten times the strength of the Decca signals had rendered the system unusable.

Captain J. HAUPTMANN-ANDERSEN (Denmark) presented IMMRAN Document No. 33, "Experiences from Denmark". This paper reviewed the progress in the installation and use of war-developed navigational aids in Denmark since the end of the war. The uses of radar, Loran, and Decca by Danish merchant shipping were described, and the progress toward operation of Decca and Loran chains by Denmark was outlined. The speaker posed several questions concerning the further adoption of the newer aids by merchant shipping.

Captain COOMBS (UK) asked the speaker if radar had been installed aboard the training ship DANMARK for the training of cadets. With regard to the speaker's remarks concerning the potential effects of radar on maritime insurance premiums, he stated that he felt that the underwriters were justified in proceeding with caution until their claims experience showed that the installation of radar and other navigational aids aboard ships justified a lowering of premiums.

Captain HAUPTMANN-ANDERSEN (Denmark) replied that radar had not been installed aboard the DANMARK.

Mr. LORANCHET (France) asked about the financial arrangements of the Decca system being installed in Denmark. Stating that there must be a decrease in the price of radar equipment, but not at the cost of lowering its quality, he asked that the question of licensing the equipment be placed on the agenda for discussion at the New London sessions.

Captain FENNESSY (UK) stated that the Decca system in Denmark was to be constructed and operated by the Decca Company for a period of 10 years, but that its operation was to be controlled and regulated by the Danish government. The shipborne receivers would be hired from the Decca Company by the shipowners, as is the case in England.

Commissioner E. M. WEBSTER (US) presented IMMRAN Document No. 34, "A Preview of Some United States Navigational Aid Developments". This paper, prophetic in nature, presented a descriptive summary of some of the systems and devices which, while not included among the systems covered by official United States policy, were in various stages of development in this country. The systems and devices discussed were the LF Omni-directional Radio Range, Navaglobe, Teleran, Lanac, DME, and the Radar Camera. The point was stressed that, while we should standardize and use what we have now, we must not be blind to newer developments for possible future use.

Mr. C. E. HORTON (UK) presented a digest version of IMMRAN Document No. 35 (U. K. Paper No. 18), "A Centimetric Rotating Beacon". This paper briefly described the progress made in the development of a 10-cm. rotating beacon, known as the "radio lighthouse", and its applications to smaller vessels due to the simplicity of the receiving equipment.

The Chairman then presented Sir ROBERT WATSON-WATT (UK), who summarized the proceedings of the IMMRAN from the United Kingdom point of view. The text of this address is given verbatim below:

Sir ROBERT WATSON-WATT (UK): Mr. Chairman, I have sought your indulgence for a departure from the submission of considered information which has been our work during this week. On this last day, while we shall be sitting together in New York City, I must ask leave to put some considerations which are by way of implied questions and appeals, rather than statements. It has been the general observation in the world of today that the ratio of available food to appetite is very un-uniform in its distribution over the world. I make no apology for the insatiable United Kingdom appetite for figures.

We have, on all occasions of this kind, done our best to submit numerical considerations as a basis for the decisions on international action. I'm going to appeal for still more numerical data to be available to us in the very precious two days at the end of the New London session when we shall have to decide what we are going to do next.

In our pursuit of figures, we have, in the London meeting, and in a form in this meeting which has not been altered in any substantial detail from that of the London meeting, submitted a table of some numerical requirements of the mariner as we believe them to stand.

We of the United Kingdom do not press the figures in that table as having a particular significance or as having universal agreement,

but we do most earnestly plead that in our New London discussion we should proceed from a table in which figures are put down, either the figures that we have given, the figures which we quote are: under 3 miles, 20 fathoms, 50 yards; 3 to 50 miles, 100 fathoms, a quarter of a mile; over 50 miles, over 100 fathoms, 5 miles. We don't mean, when we say 50 miles, something between 49 and 51 miles. When we say 5-mile accuracy, we don't mean something between 4.9 and 5.1 miles. But we do most earnestly plead that there should be an understanding amongst us all, of the order of magnitudes, of the performance that the mariner himself requires, those that he will use and demand with an urgency that is measured by his willingness to pay a specific economic price and to get his administrations to extract from him through taxation contributions to that specific price.

We must get technical figures put along side of economic figures if we are to discharge our duties. I plead, then, for a very high place in the New London agenda for the establishment of a working table, which may be the United Kingdom table, which may be a different one, but which must be a workable table in numerical terms.

If I may go very rapidly over the non-quantitative parts of the tabulation, I believe it has been implicit in all the papers prepared that we accept a separation of the services into long-distance, medium-distance, and short-distance services.

I would like to make one or two remarks on these subdivisions. On the long range aids my personal faith is well known to the many who have had the misfortune to listen to me in my arguments about navigational aids for marine and for air navigation. My personal faith is in a higher standard of accuracy than is regarded as indispensable by the mariner at this moment. I share with the United Kingdom in the view of the first IMRAMN, which said an accurate, long range aid has not the priority, the indispensability, of the medium and the short distance aids, but I believe that the long distance aids that will be provided will prove themselves, as the short distance aids have done, to be a very valuable contribution to the economics of marine navigation.

The United Kingdom holds to the view that the marine user will have to depend on the long distance aids that are provided primarily for the air user. We await, anxiously, the decision of our air bodies. We operate, for the moment, on the interim statement made by PICAO, which gives a qualified blessing to the continued and extended use in the period while we are seeking more general agreement on the systems that are typified by Standard Loran and by Consol.

I would call special attention to the fact that PICAO, however, regretfully did not recommend a universal faith in one or the other

of these. It recommended that there should be a continuation and extension within the limits of the need and of practicability of services of several kinds, including direction finding services, the Consol services, and the Standard Loran service. PICAO looked forward to the fulfillment of the relatively high promise of LF Loran, but again it's looking forward through a low visibility area in which the figures desired are obscured alike.

We cannot come to a decision on LF Loran without more numerical data than we have had. So far as we can see qualitatively, LF Loran has no overwhelming advantage to the mariner over Standard Loran; but for the air navigator it may well have the overwhelming advantage that the coverage over land areas is very much superior to that given by the standard system, and some measure of advantage will accrue to the marine as to the air user.

Of the other possible systems, the possible extensions of the Decca system, for example, some of the systems which Commodore Webster has spoken of, I will at this moment say nothing. I will continue my pursuit of figures by saying that in that pursuit we associate ourselves very closely with the remarks of the Assistant Secretary of State, in which he indicated that there should not be any inhibition of progress toward better systems of development, of promising systems, in the interests of universal standardization on an immediate and moderately good system.

We believe profoundly in standardization but in standardization only on minimum performance. We would regret any decision which greatly discouraged the development of potentially better systems. We should equally regret any failure to agree that we should use the things now at our disposal in the interests of rehabilitation of the world, which depends so largely on immediate marine navigation. We accept, with qualifications, Admiral Rose's statement that Providence has put limits on the advantages we can derive from technical aids. It is a firm part of the United Kingdom policy not to meet Providence half way in the acceptance of these limitations. We propose to have a pretty stiff tussle with Providence about the setting of the limit which Providence may have imposed.

In the medium range field we find ourselves in the closest agreement with the admirable and comprehensive appreciation of the medium frequency direction finding case, in relation to mobile stations, which has been presented by our old friend, Mr. Busignies. If I may speak personally, I accept another of Admiral Rose's statements with a special interpretation. I believe that the new navigational aids will supplement the old ones, and particularly MF/DF, but I accept the statement in much the same sense as I accept the statement that steam has supplemented sail.

We in the United Kingdom, as a matter of national policy, believe that the old advantages of the MF/DF will be required for a very considerable number of years, and we have no intention of making any dramatic or catastrophic cut in the MF/DF facilities, which on the thin analogy I have used, represent the continuity of sail from Ulysses to Admiral Mansfield; but we believe that the corresponding progression from Fulton to Commodore Manning is one which will take an increasingly prominent share and that the MF/DF service, while it must be maintained for a period which I have already suggested looks like being 10 or perhaps 20 years, should not be extended and improved in that period. We do not regard it as likely to occupy a really prominent place in the succeeding years.

For the shore-based direction finder, I would throw in one comment, only, on Admiral Rose's comment on shore-based systems. We agree about its far too easy saturability. The well chosen shore site for a direction finding station is a far more favorable site for precision measurements than anything that can be obtained on shipboard. We mustn't throw away that basic advantage of the shore-based direction finder.

On short range aids, on shipboard in particular, we are in complete, universal, unanimous agreement, but it is only a limited agreement. It is an agreement that we must have, that everywhere ships should have a ship-borne radar set. We believe we have to go further. Again, we feel that there should be no standardization which would prevent improvement. We believe that there should be standardization which would prevent, either voluntarily or by strong persuasion, the continuance of the use in marine service, of ship-borne PPI systems which no longer live up to the standards of our peacetime requirements. And the United Kingdom is giving, and repeats, a very clear and earnest plea of its seriousness on this point.

The two sets, of which we have said some 260 are in our Navy now, were on V-J Day very advanced over ship-borne radar sets. Today, on Mexico Day, they are an obsolete set. And it is our most earnest and urgent intention to withdraw from service these obsolete sets the moment commercial supplies of the peacetime, better models become available in adequate quantity. We shall be doing a grave disservice to the future ship-borne service of radar if we tolerate the continued use of sets in our Merchant Navy which no longer fulfill the requirements which we have recognized and specified.

We go further—we face the certainty, and I think I am not overstating when I say the certainty, that we shall require a certification service. It may be a voluntary certification service, it may be nothing better than the corresponding case to the sticker of the Good Housekeeping Institute, but we ought to have a

certification which relates a certain type of equipment to the minimum standards of performance on which we have all agreed.

We repeat that we see ourselves compelled to visualize an inspection service to insure continued conformity with the maintenance of the type of certified performance. We visualize, as we did at the first IMRAMN, compulsory carriage as a natural development in our radar policy. We do not regard it as an immediate necessity, as immediately desirable, as immediately possible. We believe that in a comparatively small number of years we shall all find ourselves carriedto the point where compulsory carriage will be a part of our international policy.

Looking at radar aids in the sense in which that phrase has been used, I believe, for the first time to many of us in the proceedings of this conference, I would donate a remark that it would be useful if some of us could find an alternative phrase to put in place of the phrase "radar aids" when they are applied to aids to radar operation. We have, in the past, talked of radar aids to navigation. What are now in the present papers being called radar aids, are radar aids to these radar aids. It is a very important classification. It will be a good thing to find an unambiguous word for it.

I cannot mention in ten words the importance which the United Kingdom attaches to the projects which are typified by our impending Liverpool installation described in a paper which will be made available but which will not be read here. Nor can I speak--I have already exceeded my time limit--at any length on communication. I would, however, like to say again that we believe very strongly in the necessity for a universal availability of VHF or the frequency channel allocated through the appropriate international machinery.

What is the practical application of my demand for more figures, technical and economic? I believe it is this: that within the New London meeting, or as an immediate consequence of the New London meeting, we should, I was going to say, follow PICAO. I don't know that I wish to put it in that form. We should do at least as well as PICAO in the appointment of a highly expert, international group, a subcommission whose value would rest very largely in its informality, to put down generally agreed figures about the performance of the systems we have been discussing, roughly agreed orders of the magnitude of the economic cost of these systems over a large area, because I would refer to the example of MF/DF as a case where 400 radio beacons, no one of them expensive, may be very considerable--400 times the small quantity turning into a big quantity.

I would say, and in this I speak without commitment for the United Kingdom Government, but I am sure I am supported by my Government and my Delegation in this matter, that it would be an invaluable consequence of our New London discussion if we could, at an early date, merge with tabulated agreed figures on the kind of performance, the kind of accuracy, the kind of coverage expressed in figures, and I insist on the figures, of the systems we have discussed, and of what they are going to cost us, so that administrations and mariners may decide what they are prepared to pay in good currency for known, numerical performances.

AFTERNOON SESSION, FRIDAY, MAY 2, 1947

Mr. W. N. KREBS (US) presented IMMRAN Document No. 36, "The Safety at Sea Aspects of Telecommunications as Reflected by Marine Radio Navigational Aids". This paper described the importance of a complete marine system of international telecommunications for obtaining, exchanging, and disseminating messages concerning navigation and safety at sea. Attention was drawn to the widespread need for transmitting and receiving navigational data in relation to a variety of nautical operations.

Certain undesirable aspects of the existing maritime radio situation were discussed and the need for constructive measures through international cooperation was stressed. The substantial progress already made in necessary world-wide standardization of aviation telecommunications facilities was observed and the advantages to shipping in similarly resolving its international telecommunications problems were suggested.

The maritime radio interests were urged to cooperate as an international group, including the establishment of appropriate liaison with aviation on problems of common interest, in a way to assure organized world-wide progress in efficient frequency spectrum utilization and technical standardization in accordance with the latest advances of science.

Mr. O'NEILL (UK) thanked the speaker for his paper and stated that its main thesis, the need for sticking together, had the wholehearted support of the United Kingdom. He said that it was with this end in view that the United Kingdom Ministry of Transport had circulated its proposals for marine frequency allocations to the principal maritime nations and that much useful comment had been derived from the recipients of these proposals. He asked Mr. STANESBY (UK) to tell the Meeting some of the action the United Kingdom had actually taken toward standardization.

Mr. STANESBY (UK) commented that we are all agreed on the need for standardization, and that the standardization of the marine

communication frequencies would be a great step along that road. The United Kingdom had recently formulated a series of minimum performance specifications for radar, communication, and other aids-to-navigation equipment, which would be issued in the course of the meeting.

The next paper, IMMRAN Document No. 37 (French Paper No. 1), "Standardization of Ship-Shore Telephone Communications at the Entrance of Harbors", was presented by Mr. LORANCHET (France). Taking cognizance of the need for standard facilities for the exchange of information between ships and harbor authorities, the paper proposed that two frequencies separated by 5 mc/s in the 156-166 mc/s band be allocated for this purpose and that this proposal be conveyed to the International Telecommunications Conference.

Mr. STANESBY (UK) commented that the United Kingdom was in general agreement with the foregoing paper. He added that the United Kingdom did not propose to limit the use of the two frequencies proposed to traffic between ships and shore-based radar stations but to use the frequencies for all general harbor and port-control purposes. He agreed that a separation of frequencies is desirable, suggesting that this separation be 4 mc/s.

The Chairman delivered his summary speech, which is included verbatim below (This address was originally listed as IMMRAN Document No. 38 (revised).):

Dr. EVERITT: As Chairman of the Meeting I would like to summarize the salient points that have been developed. In this summary I will not necessarily take the items up in the order of their presentation but will cover my interpretation of the general thoughts and conclusions which have appeared during the week. I would like to emphasize that I am not a Government worker nor a member of the American Delegation but merely a professor of electrical engineering science. The viewpoint which I give here is entirely my own and has no necessary relation to the United States policy. In fact, in order to maintain as impartial a view as possible, I have refrained from attending the meetings of the United States Delegation, and I have not checked my talk this afternoon with that group.

Before my discussion I would like also to emphasize that my primary forte is the assessment of technical and operational developments rather than the problems of economics and politics, so that I may err on the one side or the other through not taking appropriate consideration of the latter items into account.

I think it is apparent from the discussions we have had throughout the week that the technical progress in marine aids to navigation is far ahead of the operational applications. It is our problem

to facilitate these operational applications as rapidly as possible. Normally the development and introduction of new services occupies a considerable length of time. However, we have had a recent example of what can be done if the necessity is sufficiently great, because many of these devices have been developed and put into wide operational use during the recent war. This week we have heard of many devices. Next week you will have an opportunity to see some of them in operation.

Others, of course, especially those of foreign development, will not be available. But the problem we must face in the future is the exploitation of these and other devices which may be needed. I think the point that was emphasized most generally during the week is the desire for standardization wherever possible. We have had reiterated assurances by both the United States and the United Kingdom, the principal sources of the devices that have been described, that full technical details of manufacturing processes will be made available to all, but I recognize realistically that does not necessarily solve the entire problem. New aids do not make old ones obsolete. An improvement in navigation, I think, is necessarily a series of successive approximations rather than the achievement of the perfect at some given time.

There is need for standardization because, as a ship sails the seven seas, it is highly desirable that she shall find her aids available, the aids to which she is accustomed, in strange waters. In fact, danger is greatest in strange waters and it is there that the need for aids to navigation is most acute.

It has also been emphasized by a member of the United States Federal Communications Commission, who is an expert in allocation matters, speaking not only for the United States but, I think, stating a well recognized fact, that the frequency allocation problem necessarily will limit the number of aids. We have seen a few of the aids that have been actually developed, we have heard of new aids that are proposed. Since the ingenuity of man is unbounded, more and more aids will undoubtedly be presented in the future. There is, however, a finite density which can be assigned to the use of these aids in the frequency spectrum.

I noted in the general agreement obtained at the first IMMRAN conference that there are three distinct problems. These have again been reiterated by all groups that have been represented on the platform. These three items are: firstly, the short-range or pilotage water navigational problem; secondly, the problem of medium-range or coastal waters; and, thirdly, navigation at long range or during ocean passage. I will take up in turn a discussion of where it appears to me that agreement and disagreement has occurred or is indicated in each of these three areas.

I think there is no doubt but that there is universal agreement that radar is an important navigational aid for the pilotage problem and should be adopted as quickly as possible; also that radar gives important additional information to prevent collision and can be used in all areas where ships sail. There is no common agreement on the radar frequency which is most desirable. The United Kingdom seems to have decided definitely on 3 cm., whereas there is essentially disagreement within the United States as to whether 3 cm. or 10 cm. is most desirable. The group which is operating on the Great Lakes, where they have been able to obtain greater coordination through a very close-knit shipping association and where they have also employed a specific consulting engineering firm, has reached rather definite conclusions in favor of 3 cm.

We note that the primary difficulty in this decision is the opposing effect of two separate factors: on the one hand the need of high discrimination in which 3 cm. is superior, and on the other a somewhat more unknown situation involving reflection from rain and from sea return in which 10 cm. seems to be more satisfactory. There is a thought here, of course, that the 10 cm. problem of discrimination can possibly be achieved by the use of larger antennas. That is, the set could be so designed to achieve, with 10 cm., the same discrimination as with 3, provided the structural problems involved with the use of larger antennas can be surmounted. That may be a very serious exception. On the other hand, the problem of reflection from rain and ice crystals in the air is one that is beyond the control of man except by the proper selection of the frequency. It would seem to indicate that at least we should have more information obtained over larger sections of the glove in order finally to decide this problem.

Fortunately, in the radar problem the necessity of standardization of frequencies in the immediate future does not seem to be too great, and time is available for the use of operational research. This, of course, will probably hold up the development of the active type of beacon, which is frequency sensitive, because such beacons should be available to practically all radar sets and would require definite standardization unless we are going to have duplication of effort and duplication of cost. On the other hand, it would be my opinion that the early development of the passive repeater or corner reflector should be pushed with the greatest emphasis. It is probable that final decisions on the use of active repeaters must wait upon information and experience obtained in the development of the passive repeaters which are cheaper and which are not so frequency sensitive. It would seem that, because of this development which still needs to be considered, it is not unwise to retain at least 2 and possibly 3 frequency bands for development in the immediate future.

Again, from the limited knowledge I have of the problem of frequency assignment, it would seem as though several bands are quite possible in the microwave regions, because, in terms of frequency assignment that region is not as yet congested, such reservations could probably be secured. At a later time, if a final settlement is made, undoubtedly other services will have developed which will very effectively use any bands which might be vacated.

Another point which has been emphasized by a number of people is that radar will pay for itself through a saving of time, if for no other reason, so it is highly questionable as to whether a cheap radar would be indicated if such cheap radar means the sacrifice of the facilities for pilotage in congested waters. The purchaser of such cheap radar would only be saving money in one payment at a much greater expense in others. This, of course, does not apply to pleasure craft, where funds available are limited and where no direct economic relation can be shown between time saved and cost of installation.

It has also been mentioned by a number of speakers that economies in insurance rates should be hoped for in the future but that we cannot expect these immediately until the underwirters have had a chance to obtain statistical information upon the actual statistical results in terms of safety of property at sea.

It was mentioned that radar should be operated by the ship's navigation officer in order to obtain the greatest effective use of this aid. In fact, in general, any operation which can be secured by the navigation officer removes one intermediary and therefore gives more rapid, useful data and allows immediate action resulting therefrom.

There has been a discussion of the matter of licensing and it would seem that the United Kingdom has gone further in regulating radar with a view to licensing than has been true in the United States. The United States specifications carry primarily the weight of the approval of the Radio Manufacturing Association in this country, which has standardized the specifications and has done important component standardization in this field. Essentially, in the United States, the selection is left to the individual company to decide which radar they wish to purchase. The specifications are practically the same in both countries. However, it has been recommended here that standardization is desirable, not only from the standpoint of frequency operation, but also so that officers and components and maintenance facilities can be interchanged in all areas of the globe.

I think we come, however, in the short range area, to one basic difference in recommendations between the United States and the

United Kingdom. The United Kingdom essentially believes that an additional aid is needed for short distance purposes and proposes Decca. The United States, on the other hand, appears to believe that no additional aid is needed, provided active or passive beacons can be used as well. Decca appears to be an extremely accurate device, but we recognize that it needs lane identification and we are promised that such lane identification will be available.

I think that it is recognized that the development of adequate lane identification is essential or the mariner may be in the situation of a flea who can tell which hair he is on but not which dog.

Decca involves integration which required knowledge of a definite starting point, and the United States Delegation seems to question the difficulties of using this integration when it is necessary to enter the system from outside the area covered by the Decca system. Since this integration must be continuous, it seems apparent that an independent power supply would be required, starting with the prime mover itself, and continuing through the complete power system. I note also that it has a mechanical interpretation of the signal intermediate between the equipment and the visual presentation.

I think it will be recognized that, in general, visual presentation of data is somewhat superior to aural presentation, but it must be recognized that, if this involves the operation of relays or other discriminating devices, noise is an important factor at times when the signal to noise ratio is insufficient.

Coming next to the medium range, I think the major point of difference at the present time--and I am pointing out the differences as I, personally, see them--is that the United Kingdom essentially urges Decca and believes that medium frequency direction finding, if not obsolete, is at least so obsolescent that its early demise may be expected.

On the other hand, it appears that the United States still believes in direction finding. As an indication of that, they are going to ask for an increase in the band, from the present 30-kc. width to a 40-kc. width, at the forthcoming conference. It has also been emphasized by some that MF/DF is not completely on its last legs because new developments should be considered, and examples of some new developments were presented.

Developments in the very high frequency range may also be important. One factor which I think all engineers recognize as inherent in the D/F system is that it suffers from the fact that the reading is

taken under minimum signal conditions, and, therefore, the signal to noise ratio drops at the critical point, the noise rising at the instant of observation. This inherently gives us a certain indeterminancy which required interpretation.

Cathode ray presentation of the signals of either D/F or other methods would seem to offer improvement because it is inherently easier to interpret and detect inaccuracies whenever there is a visual presentation in the form of a cathode ray indication. There is a great deal of information in a cathode ray presentation, most of which is not used in times of good signals, but which can be interpreted by experienced observers when the signal to noise ratio is poor. This, it would seem, has not been sufficiently explored nor has sufficient quantitative data been secured about it.

The large number of present installations of MF/DF indicates doubt of the early decease that has been predicted or that beacons should be abandoned. Above all, we recognize that small boats will need D/F for a long time because of the inherent cheapness of that type of observation.

In connection with the discussion between the various interpretations of the medium frequency problem, and also the long range problem, it might be well, however, to recognize that there is an inherent improved accuracy when we measure distance, or difference in distance, as compared to when we measure angle. That is, inherently those devices which belong to the hyperbolic group are more accurate than those that use angular measurements. In this respect Decca seems to have a decided advantage over D/F. The problem is, of course, that a final decision must be reached, taking into account both the technical advantages and the costs.

When we come to long range, there seems to be a variation of opinion as to the importance of long range navigation--varying, I would say, from an attitude of coolness to warmness--not, however, going as far as a cold reception in any case.

I note particularly that in the United States, the spokesman for the National Federation of American Shipping does not seem to agree with the skipper of the leading United States ship as to the importance of long range navigation. Commodore Manning, as an operational officer, emphasized very definitely the importance of long range navigational aids. In fact, in his very enthusiasm, I think perhaps you may recognize the reason for some of the difficulties which confront us. A skipper who is presented with new radio devices frequently becomes so enthusiastic about the particular device that he is using that he is sure it is the only device that should be considered and that all others inherently must be poorer.

I think, therefore, we should observe with a certain amount of caution the recommendations of skippers who have had experience with a limited number of devices. People generally do not want what they have never had, but after they have it they are sure that it is a necessity rather than a convenience or luxury.

In the long range field I think we should recognize the importance of early decision on standardization for marine radio aids if we wish to have an important voice in their final determination, because it was recognized by all who spoke that the long range navigation system must be common to aviation and marine application.

Existing disagreements in the air leave an opportunity for the surface goers to make up their minds and have an important voice in the final determination. If such an agreement cannot be obtained between the several national groups who are interested in marine navigation, I feel sure that the final determination will be obtained without their advice or perhaps even their cognizance.

Long range navigation necessarily should have wide area coverage. It is quite important that the installations themselves be world-wide, or they will be greatly restricted in their applicability.

Here we come again to a difference of opinion between two groups. We note that the United Kingdom urges the Consol system. The big advantages of the Consol system, as I observe it, are the narrow band width which is used and the fact that only a communication receiver is necessary, involving, therefore, a simple installation that can be used by ships of all sizes. The operation involves a problem of counting and has ambiguity which must be resolved, so that it must be supplemented by direction finding in order to locate a particular lane.

Like D/F, Consol involves a minimum signal determination at the point of most important reading and has aural presentation. However, unlike D/F, it does not require calibration of the ship installation, which is certainly an important improvement.

We note that operational research on the Consol reports that the Consol compares favorably in accuracy with celestial navigation.

Now, as opposed to the primary support of the United Kingdom for Consol, the United States proposes the Loran system. As one of their major arguments they point out that it has been tested by operational experience in a number of installations running into the thousands, that it has been installed over quite a large portion of the Northern Hemisphere, and that it has the advantages of a pulse system, of cathode ray presentation, and of hyperbolic system.

The advantage of the pulse and cathode ray system is particularly important when you come to long range because long range always involves the problem of sky waves, as has been mentioned. It has also been mentioned that, if we do not have the desired accuracy at a given time, it is next most important to have a situation where it can be recognized that such inaccuracies exist. In presentation of the data on a cathode ray oscilloscope, the additional information is available that the reflections are changing, because one can recognize the characteristics of reflections from the ionosphere to quite a large extent when observing the shape of the pulses.

It has been pointed out that Loran offers a very good possibility for extension to low or very high frequencies, using practically the same equipment on the ship and involving only the addition of a converter. Loran has the disadvantage that a wider band is used, but this is overcome to quite an extent by the fact that it uses time division. Time division in any communication or navigation system makes possible the transmission of additional information in the same band width as the single pulse. This is accomplished in Loran by using a large number of stations on the same carrier frequency, with different pulse frequencies, so that the signals from different pairs of stations can be separated.

It has been mentioned that interference has been observed on Loran stations, and it would appear that this is very similar to that experienced with some of the early CW stations, especially those that were engineered in a hurry. The interference problem is similar to that of key clicks. This problem has been solved by improved circuits, and the new Loran equipment occupies a narrower spectrum.

The newer Loran installations have a wider variety of pulse rates, increased power in the transmitter; and in the receiver the use of mechanical counters and dual presentation has been developed.

Many new systems were proposed today in the summary papers by both the United States and the United Kingdom representatives, indicating to us the fact that we must always expect new systems to be proposed and that, therefore, we will have to consider primarily the operational results of existing systems in order to secure standardization, as we shall always be anticipating the ideal system.

In other papers, we have had an emphasis on the importance of the importance of the radio telephone as an ally to all other aids. There is agreement between the United States and the United Kingdom representative on the necessity of a VHF band of approximately 10 mcs in width in the neighborhood of 180 mcs. There appears to

be a necessity for studying the particular problems of small boats, because naturally the emphasis of commercial interests is applied first to applications to the larger ships. If we remember the large number of small ships, we must not pass them by in considering either standardization or their needs. It would appear that the numbers of these boats is sufficient to justify extensive development and operational study.

If I might, in summary, point out primarily the disagreements, I think the United States emphasizes that they wish to utilize the experience of aids that have been in actual operational use for some time, particularly in terms of war experience, and which, therefore, while new to the shipping interests, are old in an operational application; while the United Kingdom recommends the addition of some devices which have indication of great accuracy or simplicity but where questions of operational experience still must be raised. It must be recognized, however, that we cannot refrain from using new devices just because they are new. If that were the case we would indeed be in a sorry situation.

These disagreements involve, for short range, the question of using radar with beacons, as advocated by the United States, or using Decca, as advocated by the United Kingdom; for medium range, the use primarily of MF/DF, as recommended by the United States, or the use of Decca, as recommended by the United Kingdom.

It would appear to me that the United States has not offered sufficient engineering data as to the relative inaccuracies of MF/DF. Observing the situation from this platform, I believe I must bow to the United Kingdom representatives as offering more complete data in their comparison between some of these devices and the recognition of the limitations in a quantitative manner, a respect for numbers which has appeared to me to be lacking in the case of some of the United States papers.

In the long range field, we have essentially Loran, recommended by the United States, and Consol, recommended by the United Kingdom. Loran is recommended by the United Kingdom as a secondary device, and one of their papers points out the disadvantages of Loran. There does not appear to have been any comparable discussions from the United States as to why they do not consider the Consol system advisable.

There appears to be some slight difference in the operational requirements of the United States and the United Kingdom as observed in the United States policy presented on the first day and the United Kingdom policy as presented by Captain Ravenhill. The United States policy was copied word for word from paragraph 7.19 in the agreement of the general summarization of Volume 1 of the First IMRAMN Meeting;

whereas there is some slight deviation from this in the table which was presented by Captain Ravenhill. I think it would be well to do what Sir Robert suggested this morning and see if we cannot start with a definite table at a future meeting and resolve these differences or see if such differences exist. The slight differences that do exist are somewhat modified in the text of Captain Ravenhill's paper. This problem involves whether tolerances should be presented in the table itself, that is, the ranges which are permissible, or whether they should be in an appended discussion. It may be that, if we cannot resolve our differences in a meeting like this, we do not have sufficient information and need operational research on an international level.

It must be recognized that operational research is especially needed where performance involves equipment plus people, and that is decidedly the situation here. I want to echo Sir Robert's plea for figures. It has also been a hobby of mine for many years. I believe that, without quantitative data, decisions are apt to be mere guesses. Operational research, if performed, must be completely objective. It should preferably not be conducted by the advocates of either side, if such a situation can possibly be obtained. Not only must the investigators be impartial, but they must be recognized as impartial by those who are to use their findings.

It was recommended by Sir Robert that an international group should put down the figures on performance and cost and other items and merge the tabulated figures. I believe that such a group might also very well emerge with a proposal for such operational research as may be needed to determine the requirements, if we cannot reach an agreement in the course of this meeting.

Incidentally, I brought out of my own file this morning a report which I am going to have distributed to you, which developed out of an operational research project in the Signal Corps. It was started in the Signal Corps during the war and it has been continued by the Central Radio Propagation Laboratory to whom a number of the original group transferred following the war. This group is associated with the National Bureau of Standards of the United States. The paper is CRPL-4-1 on the "Comparative Accuracy of Various Existing and Proposed Navigational Systems." It involves only a theoretical study of these systems; however, this has been followed by a preliminary study of the LF Loran by actual operational research data. I think it indicates a possible way in which actual accuracy can be evaluated.

Since, I believe, there is definite agreement that we ought to get together and emerge eventually with specific recommendations,

I propose the establishment of an immediate international steering committee and wish to propose specific names. I recognize that there is a problem in selecting a list and I have selected this one with a certain distribution in mind. They are not intended to represent their countries as such but to help us get together and create an agenda from which the conference itself can emerge with recommendations. Such a Steering Committee must be quite small in order to accomplish the desired results in the time available.

I would like this committee to help me in preparing the agenda for Thursday and Friday. I propose that this committee meet initially on the ship going to New London at three o'clock Sunday afternoon. The proposed committee is De Albuquerque Guillobel of Brazil, Mr. Fraser of Canada, Mr. Wei of China, Mr. Hauptmann-Andersen of Denmark, Mr. Loranchet of France, Lieutenant Soubassakos of Greece, Mr. van Anrooy of the Netherlands, Mr. O'Neill of the United Kingdom, Mr. Raev of the Union of Soviet Socialist Republics, and Mr. Webster of the United States Delegation.

If any of you have specific suggestions as to points that should be covered on this agenda, I would be glad to have you convey them to me or any member of this committee. If any member of this committee does not feel that he can serve, I would appreciate it if he would see me immediately after the Meeting.

I would appreciate your cooperation in getting the agenda ready, so that we may be sure that nothing of interest is omitted. It will be expected that, if we forget certain items on the agenda, the members will be free to bring them up in the Meeting as well as give us any suggestions coming to us in advance.

Thank you, gentlemen, for the cooperation you have given this week.

The Chairman then presented Congressman FRED H. BRADLEY, Chairman of the Merchant Marine and Fisheries Committee of the House of Representatives, whose remarks follow.

Congressman BRADLEY: Mr. Chairman and Gentlemen, I bring you the good wishes of the Congress of the United States. I am sorry that not more of us were able to get away from the House of Representatives today, but several of my colleagues will join me tonight. We had hoped to have about 16 members of the 25-man Committee on Merchant Marine and Fisheries present.

Yesterday I had five different subcommittees meeting simultaneously, taking testimony on various things that are of great importance to you, to the American Merchant Marine, and to American and international fisheries, as well.

The Congress is in session and I am hopeful that by Sunday several more members of the committee will join us and, certainly, some of our advisers, because we are intensely interested, as you all are, in this international program of radio aids to navigation.

It is a great pleasure to be with you and I'm sorry we couldn't be here all week; but as Congress is in session, our first duty is there. It is a great pleasure to greet you on behalf of the Congress of the United States, and I am glad to see so much interest in this very important problem.

Commissioner WEBSTER (US) thanked the Chairman for his summary and for his conduct of the sessions during the week. Sir ROBERT WATSON-WATT (UK) joined in the Commissioner's remarks on behalf of the visiting delegates. This concluded the formal sessions at New York.

CHAPTER III

PRACTICAL DEMONSTRATIONS OF AMERICAN EQUIPMENT

On Saturday, May 3, 1947, the delegates visited the United States Maritime Commission Training Facilities at Kings Point, Long Island, and at Sheepshead Bay.

On Sunday, May 4, 1947, the scene of IMMRAN was transferred to New London, Connecticut. The majority of the delegates made the trip aboard the United States Maritime Commission Ship AMERICAN SAILOR, one of the demonstration ships. A few went aboard the Coast Guard Cutter CAMPBELL; others, by special bus and train.

The first 3 days in New London, May 5-7, inclusive, were devoted to demonstrations of the various American equipments aboard vessels operating in the vicinity of New London. The demonstration ships participating were the AMERICAN SAILOR, the Coast Guard Cutter CAMPBELL, the United States Coast and Geodetic Survey Ship LYDONIA, and the Sperry Gyroscope Company's motor yacht WANDERER. The delegates were divided into three groups, each group spending one day on each of the first vessels mentioned and the third day aboard one of the latter two ships, depending upon which of these they most preferred to visit.

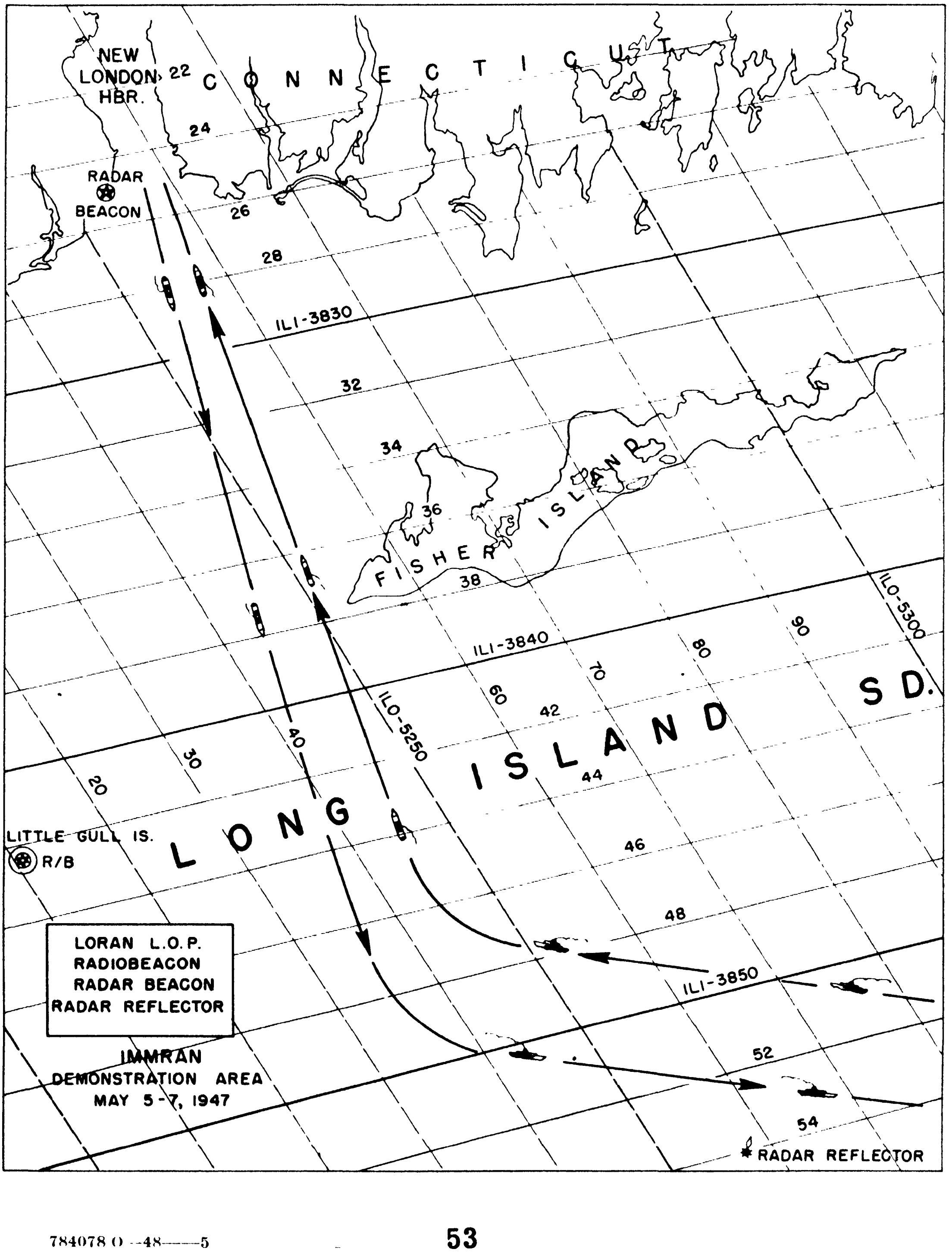
The AMERICAN SAILOR was the primary radar demonstration ship. Five American manufacturing companies, General Electric, Raytheon, Radiomarine Corporation, Sperry, and Westinghouse, had installed their commercial radar sets aboard the ship especially for these demonstrations. Three of these radars operated on a 3-cm. and two on 10-cm. wavelengths. This gave the delegates a good opportunity for side-by-side comparisons of the principal commercial radars of the United States. In addition, a corner reflector had been installed on a navigational buoy and one Ramark equipment was set up on the shore.

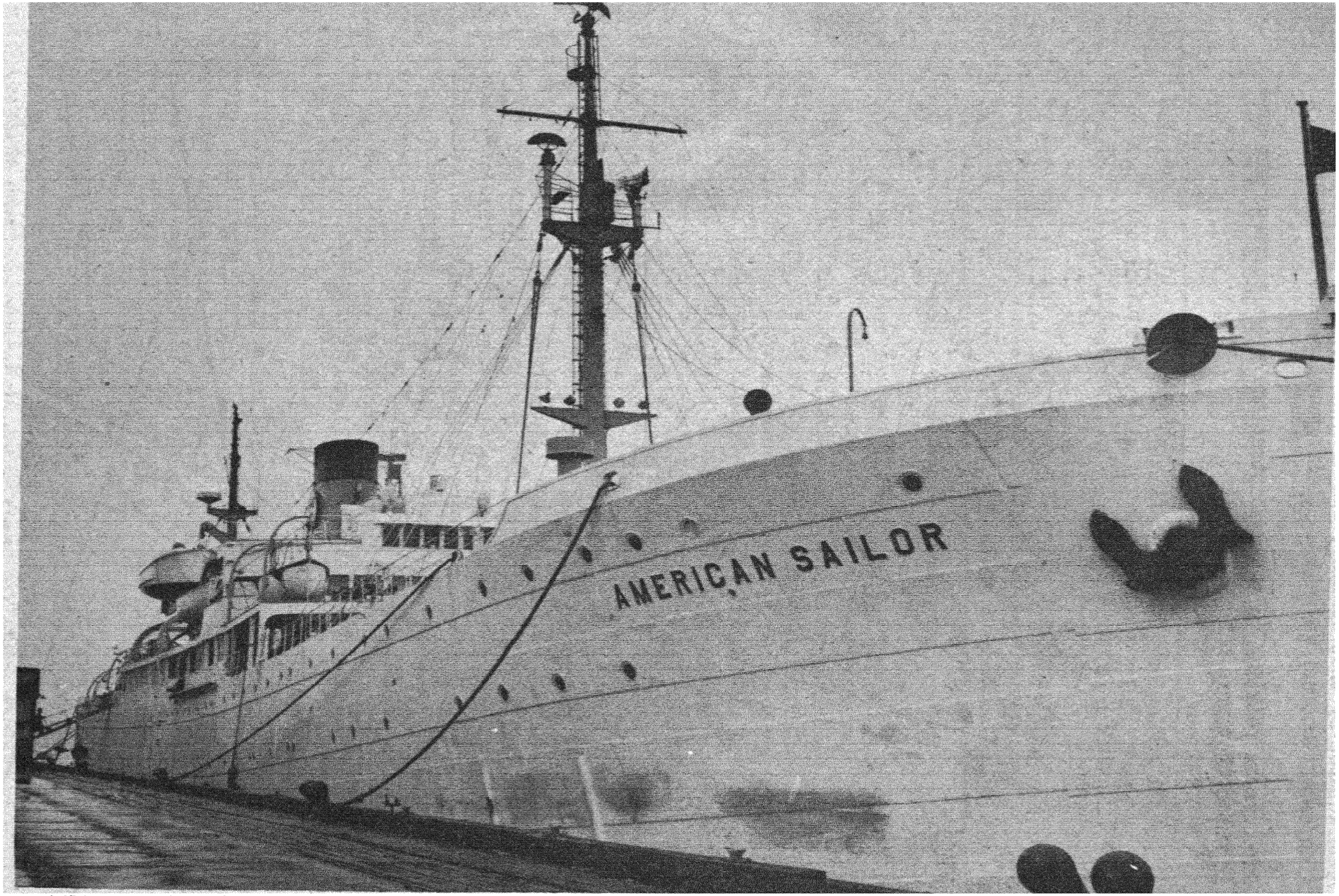
The United States Coast Guard Cutter CAMPBELL was equipped with several additional Loran receiving equipments made by the Sperry Gyroscope Company and the Radiomarine Corporation of America and one prototype equipment of the Philco Corporation. Special charts were provided, and each delegate was allowed to use the equipment personally.

The United States Coast and Geodetic Survey Ship LYDONIA demonstrated the Shoran equipment used for hydrographic survey work. The Sperry Gyroscope Company's motor yacht WANDERER, which is

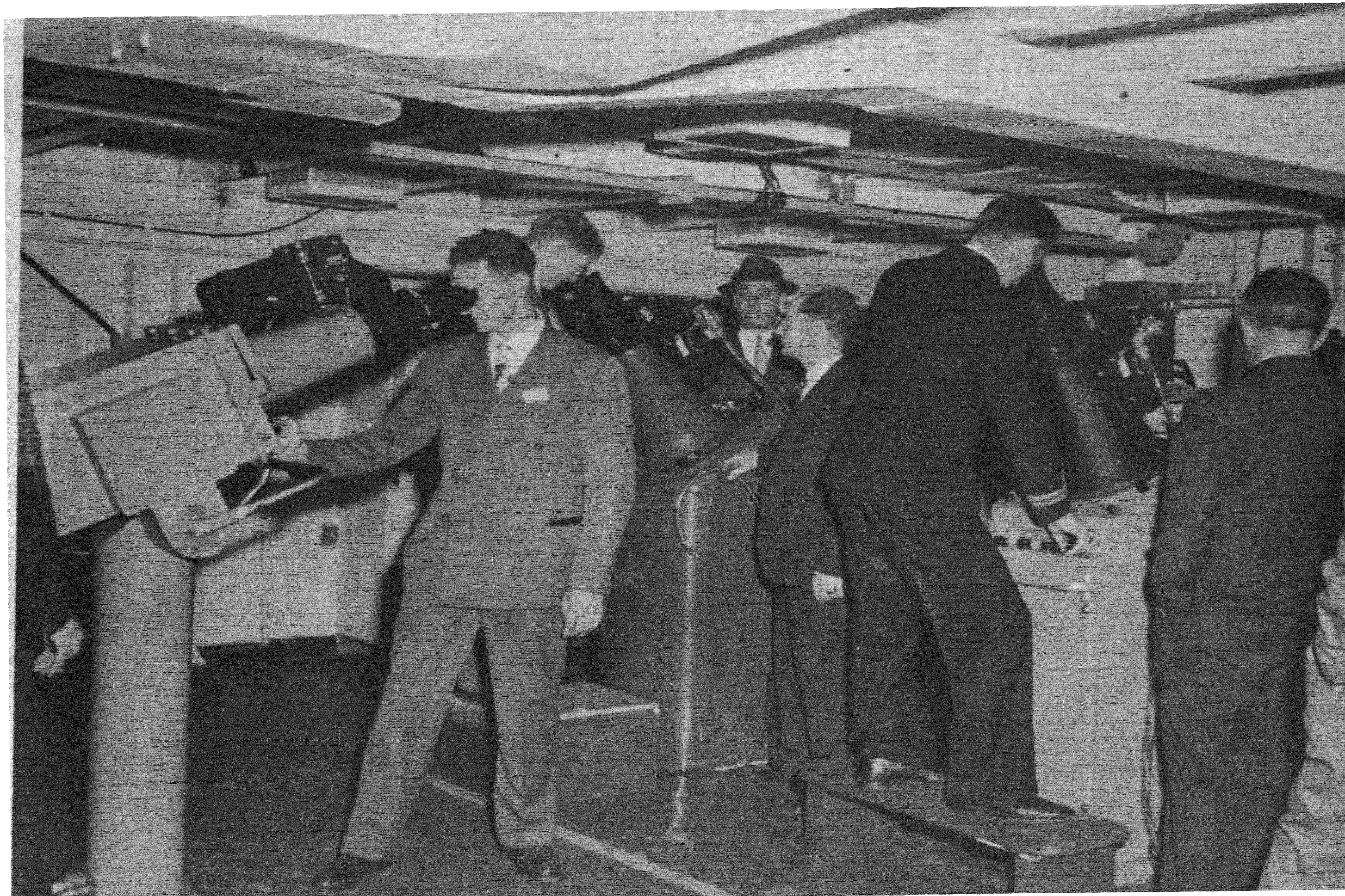
equipped with practically all the electronic aids to navigation manufactured by that company, demonstrated all the above-mentioned aids except Shoran, as well as their gyroscope and fathometer.

Photographs relating to the demonstrations and a chart of the area in which they were held follow.



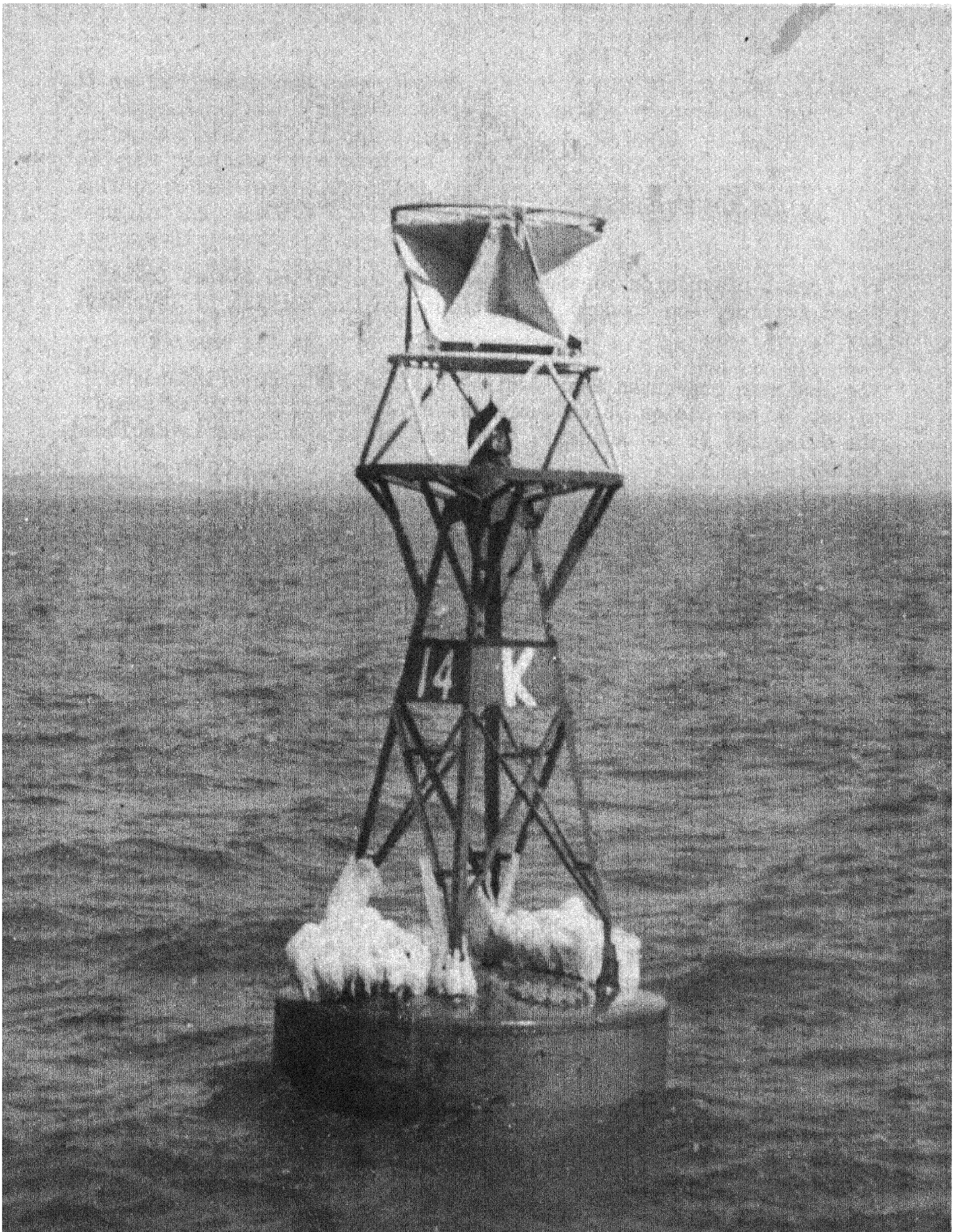


The **AMERICAN SAILOR**, showing antennas of demonstration radars, as follows: foremast, left to right, RMCA (3-cm), Raytheon (10-cm), Sperry (3-cm); bridge, General Electric (10-cm); aft, Westinghouse (3-cm).



Forward radar demonstration room aboard AMERICAN SAILOR. The radars seen, left to right, are the Raytheon Pathfinder (10-cm), Sperry (3-cm), and Radiomarine (3-cm). The supplementary equipments mounted above each of the radar 'scopes are Fairchild Radar Cameras, used for recording the radar images.

Delegates participate in Loran demonstrations aboard the Coast Guard cutter CAMPBELL.



Trihedral radar corner reflector of the type demonstrated at New London.

CHAPTER IV

NEW LONDON SESSIONS: TECHNICAL DISCUSSIONS

The formal discussion sessions opened at the United States Coast Guard Academy, New London, Connecticut, on the morning of Thursday, May 8, 1947.

The Chairman presented Rear Admiral JAMES A PINE, Superintendent of the United States Coast Guard Academy, who officially welcomed the delegates to the Academy. The text of this address is included below:

Rear Admiral PINE: Mr. Chairman and Delegates to the International Meeting on Marine Radio Aids to Navigation, I am very glad to welcome you to the closing sessions of your meeting at the Academy and hope that we may be able to continue the good weather that seems to have come to us this morning. I would like to pay tribute to the member of the Secretariat, whoever he is, who has furnished the weather for your meetings. I think that the weather conditions during the tests when you went out on the ships were perhaps as severe a test of the things that you wished to see in connection with the cruises that could have been furnished, and I hope that that member of the Secretariat will continue his favorable weather for the rest of the sessions.

Mark Twain, who was a Connecticut Yankee, although he started out by being a Mississippi River pilot, once said of New England weather that people talked about it a good deal but that no one seemed to do anything about it. I think that your staff here has done something about the weather and I hope they keep up the good work.

In welcoming you here after almost 2 weeks of work, I feel that an appropriate salutation might be the Hawaiian word "aloha", which implies not only greetings but affection and the hope of a future meeting. And so I would like to leave the thought with you that we are very glad to have you here and that we hope that we may have the pleasure of your company some time in the future.

The development of radio aids to navigation is, of course, a very live subject with the Coast Guard. We are interested in all phases of safety and security at sea and we realize the complexity and the difficulty of securing that very desirable end. The development of many marine radio aids to navigation came during the war, and because of that fact the general public knew very little about them until comparatively recently.

It is important that the general public should be informed of the importance of radio aids to navigation in the general picture of safety at sea. It is quite possible that, without having witnessed all the miracles that came out of the war, they may feel that safety at sea may be obtained by blowing horns and banging on tin pans in the same way that the ancients thought that they might avert eclipses of the sun. It is important, not only for those who are technically responsible for these developments, but for the governments, as well, that the public should realize the importance of informing people regarding the developments along the lines that you gentlemen are experts in. Otherwise, I am afraid that the feeling of the public might possibly be similar to the man who observed the operations of a lighthouse and said, "Lighthouse no good, light he shine, foghorn he blow, bell he ring, fog come in just the same."

Lieutenant Commander L. E. BRUNNER (US) briefly summarized the results of the demonstrations of the preceding 3 days. He announced that a complete display of Loran shore station equipment and shore-based radiobeacon equipment was set up in the conference building. The delegates were cordially invited to visit this display.

The Chairman indicated he had been given a number of questions by the various delegations, which he would present in order.

The first question was from the Delegation of Portugal: "With regard to radar and Loran installations aboard ships, besides the cost of the equipment, what may be expected relative to the duration and costs of components for replacements, i.e., magnetrons, klystrons, cathode ray tubes, TR switches, etc.?"

Lieutenant Commander McNALLY (US) said that the current prices of these components were not at all indicative of what the costs would be when radar becomes a well established device in the maritime services. Current prices for cathode ray tubes were about $25; for magnetrons, about $100. However, all these prices might be expected to decrease when quantity production and more standardization take place.

Mr. CURTIS (US) concurred in the opinion that prices of components would decrease when quantity production became possible. He cited cases of several radar equipments which had operated between 2500 and 3500 hours without the replacement of magnetron, local oscillator, TR tubes, or cathode ray tubes. He believed that, in general, these special tubes had life expectancies of at least 1000 hours, and that this figure could be expected to increase as experience is gained.

Sir ROBERT WATSON-WATT (UK) added that the United Kingdom situation as regards manufacturing arrangements and the like is so closely

special grounding precautions, and, in general, a combination of all the devices together might possibly result in reduction of the interaction.

Captain HARDING (US) stated that interference to the Loran receiver-indicator was not normally a serious problem, provided the normal precautions of keeping a reasonable separation between antennas and using filters in the power supply lines were observed. He stated that he had observed the simultaneous operation of Loran and communication equipment in the restricted space of a trans-Atlantic aircraft and that no difficulty was encountered.

The next question, submitted by the Portuguese Delegation, was: "In case any aid other than radar is adopted to replace MF/DF for short- and medium-range navigation, what types of equipment might be used to find at sea a ship, aircraft, or lifeboat sending out distress calls out of the range of radar?" This question was accompanied by a statement from the Delegation of Portugal that they believed that MF/DF is still, and will continue to be, a valuable aid to navigation and to rescue at sea.

Sir ROBERT WATSON-WATT (UK) replied that he did not believe the question to be one of urgency, as the shipborne direction finder would continue in use for many more years, particularly in its search and rescue application.

The Chairman then opened the meeting for other questions which might have been left pending from the New York sessions.

Mr. MANSON (Union of South Africa) asked what were the best and worst accuracies that can be achieved with Shoran equipment.

Lieutenant Commander BURMISTER (US) replied that an attempt was made to hold the error within an area having a diameter of 25 feet. At 50 miles offshore this is of the first order of triangulation. The equipment was believed to be capable of producing an error of 25 feet from the true position. This figure had been arrived at by considering personal error, permanent equipment error, and two transient equipment errors, and assuming all these factors to be cumulative. The fact that some of these four variables will normally be compensatory would tend to keep the error within this outer limit. The foregoing errors apply to those of a single line of position; the final positional error is necessarily affected by the angle of intersection of the two lines, being least at 90 degrees and increasing as the angle decreases.

Sir ROBERT WATSON-WATT (UK) stated that the United Kingdom, through its experience with the "Oboe" system, was not convinced that accuracies of the order given by Lieutenant Commander BURMISTER were

attainable under normal operating conditions, for the reason that the velocity of propagation is not known to the accuracy suggested by the figure of 25 feet in 50 miles. He stated that the velocity of propagation is known to one part in ten-to-the-fourth-power but not in one part in ten-to-the-fifth-power. This involved two considerations: the normal velocity and the average velocity over a particular territory involving the eccentricity of the earth's surface. There is a variable part of the velocity due to the effects of the lower atmosphere, not ionospheric, not due to reflection affections, but to the reflective index of the air near the earth's surface. For these reasons, the United Kingdom was somewhat cautious in supporting or accepting statements to the marine surveyor that he may reasonably count on accuracies of the order of 25 feet in measurements over 50-mile distances.

Lieutenant Commander BURMISTER (US) replied that there were factors which produced variations in velocity, barometric pressure differences being one of the greatest. While the velocity of propagation is not known to within 10 miles per second, the distances at which Shoran is used are such that this factor does not introduce prohibitive error. He did not agree with the statement of uncertainty and variation of the velocity of propagation and stated that this could not easily be calculated.

Lieutenant SOUBASSAKOS (Greece) asked if numerous islands and high coastline, such as are found in Greek waters, would introduce adverse effects on the Decca system, due to variations in propagation velocity or reduction of range through signal attenuation.

Mr. ROSS (UK) replied that no reduction in range would be anticipated under such conditions, as the signal strength is normally adequate at ranges considerably in excess of the 300-mile limit. He believed there would probably be some variations in velocity due to the terrain but did not believe these important for normal navigation. There have been noted small systematic deviations in the English Decca Chain, on the order of 40 to 50 yards, which may be due to this factor. He stated that in any electronic survey system, the accuracy may be improved by establishing a monitor station in order to make allowances for small systematic deviations.

Captain FENNESSY (UK) added that observations on the English Decca Chain, in areas with mountains intervening in the signal path, namely along the Welsh Coast, the southern part of Norway, and in the south of France, had not revealed any perceptible errors due to this factor.

Mr. WANG (China) asked concerning the results of the tests of the Shoran equipment on land. He also wished to know the cost of a complete Shoran system.

Lieutenant Commander BURMISTER (US) replied that, while he had not personally participated in Shoran measurements over land, there had been tests conducted in the vicinity of Denver, Colorado, in which lines as long as 310 statute miles had been measured, using an aircraft and five ground stations. The altitude of the aircraft was measured by the electronic altimeter and the Shoran distances reduced to map distances through rather complicated formulae. The lengths of the lines measured were known geodetically by first-order triangulation to one part in 25,000. In almost all cases the Shoran distances were in agreement to better than one part in 10,000, the accuracy of second-order triangulation, and, in many cases, were better than one part in 20,000. Since that time the equipment had been modified somewhat, but he had no figures of results since the modification. In general, Shoran had been found to be a very practical method for rapidly extending geodetic control into areas which had never been surveyed and in which the highest accuracy is not required, since Shoran measurements compare favorably with second-order triangulation and, in many cases, approach the accuracy of first-order triangulation.

He believed the cost of a single Shoran system, consisting of two ground stations and one ship station, to be in the vicinity of $35,000 but stated that this figure might be in error by as much as 50%.

The Chairman next presented Dr. FREDERICK H. SANDERS (Canada), who made the following statement with regard to the RXF/268 radar sets which had been installed on Canadian merchant ships.

Dr. SANDERS (Canada): As you undoubtedly know, the RXF/268 is a 3-cm. shipborne radar which we of the Canadian National Research Council developed for the British Admiralty and which was manufactured by Research Enterprises Limited, Toronto, during the war years. Of the 1600 sets manufactured, approximately half were delivered to the United Kingdom before the close of hostilities and the balance remained in Canada. Sir Robert Watson-Watt has stated that approximately 260 of these sets have been installed on British ships pending the production of a suitable commercial set to supersede them. In Canada approximately the same policy is being followed, and to date 120 or so equipments have been installed on merchant ships. A large number of reports on their performance have been received from the various shipping companies using these equipments, and all have been extremely favorable. The Canadian Government has been supplying these sets on a rental basis for specified periods. This is an interim measure to introduce radio aids and to provide Canadian ships with this service until such time as they can be replaced by a commercial set of proved serviceability and sufficiently improved performance.

The statement has been made that the RXF/268 is an obsolete set. We quite agree; from the developmental point of view, it is probably true that any newly developed equipment is obsolete before it is produced—but it is a matter of degree only. The RXF/268 set was designed for naval use. Its construction is, accordingly, considerably more rugged and of probably higher quality than that which would normally be called for in a commercial set for civil use. Since it was designed to fill a naval function, the set, as produced at the factory, has certain characteristics which might be considered as limiting its usefulness for civil navigation. The most outstanding of these is the minimum range. Since the decision to install these sets on merchant craft, however, certain modifications have been developed and, in many cases, are now installed in the Canadian sets. For example, the circuits have been revised to give a guaranteed minimum range of 100 yards. Two other characteristics which may be desired for merchant marine use are the incorporation of "swept gain" and an inter-connection with the compass to give true heading rather than ship's heading. The "swept gain" modification is available and can be fitted, if requested, though we do not consider this an essential requirement. The compass stabilization is a more involved mechanical modification but, again, can be supplied if required.

The points which I have indicated above apply to the RXF/268 sets remaining in Canada. With these modifications, we are confident that the RXF/268 sets will meet all the important requirements of any present merchant marine specification, and, in actual fact, the set will give the performance claimed for most existing post-war marine radars. The set was built to very exacting specifications under the "eagle eye" of representatives of the British Admiralty and of the Inspection Board of the United Kingdom and Canada. By commercial standards the equipment is probably considerably "over-engineered", and for that reason its performance has proved to be exceptionally reliable.

Before closing, I should like to read the following technical report from our Marine Radar section, which summarizes in a little more detail the modifications which are available to existing RXF/268 sets:

> "The most important modification has been the reduction of minimum range to 100 yards. This has been accomplished by a very minor change in the A.F.C. and Gain Control circuits that requires only about two hours work on the part of a service man. The original poor minimum range of 200-odd yards was due to momentary instability of the local oscillator immediately after the transmitted pulse. The modifications have now stabilized the local oscillator frequency and all echoes can be followed right into the ground pulse for

the required 100-yard minimum. Several sets have also been tested with a modified pulse line for 1/4 microsecond which gives a minimum range of 50 yards. No definite request from purchasers has been received for this modification, and only laboratory models have been modified. This involves slightly more expense and probably reduces the maximum range slightly. There is considerable improvement in range discrimination.

"Several ships requiring remote turn-on have had this feature added. It is relatively simple, consisting essentially of a time delay relay in the high voltage circuits of the modulator. Remote gain control has also been incorporated in special cases, as well as remote range selection, both of which are very simple and can be modified by any service man, if it is so desired. Swept gain circuits have been developed, but we do not agree that this feature is as essential as it is made out to be."

TABLE

Characteristics of Type 268 Radar

	War Time Model	Modified Model
Type of Presentation	Continuous PPI	Continuous PPI
Operating Frequency	9320-9500	9320-9500
Input Power to Radar Set	1 KW	1 KW
Total Drain on Ship Supply	1.6 KW	1.6 KW
Peak Power Output	30 KW	30 KW
Pulse Repetition Rate	500	500
Pulse Length	0.75 microsecond	0.75 microsecond
Minimum Range	400 yards	Less than 100 yards
Maximum Range	30 miles	30 miles
Antenna Speed	22 R.P.M.	22 R.P.M.
Bearing Resolution	3 degrees	1.5 degrees
Range Resolution	150 yards	150 yards
Antenna Beam Width		
Horizontal	3 degrees	1.5 degrees
Vertical	17 degrees	17 degrees

Captain ALCANTARA (Argentina) asked if any other radar systems had been used extensively for geodetic survey work.

Captain FENNESSY (UK) said that the Decca system, while falling under the heading of radio rather than radar, had been applied to geodetic survey. The Admiralty was using it at the moment, and the Danish Government proposed to exploit it for the hydrographic survey of Western Greenland. The Decca system claimed an accuracy of

about 20 meters at 50 to 75 miles, and about 40 meters at 100 miles, though these figures were very general and subject to variations due to system geometry.

Lieutenant Commander BURMISTER (US) stated that another device, known as "radist", was being tested in the United States, but he did not have a great deal of information on it. The equipment is small and it should be practical for short lines up to 25 or 30 miles.

Sir ROBERT WATSON-WATT (UK) stated that it was extremely difficult to give a fair picture of the performance of electronic aids in the complex applications of geodetic survey within the limits of the IMMRAN discussions but that the United Kingdom would be glad to make available considered written statements on this subject, either in the International News Letter or as a part of the IMMRAN documentation.

Lieutenant Commander McNALLY (US) added that radar was being used for survey work on the continental shelf but that for this purpose accuracies on the order of 100 yards were acceptable. He felt that this operational requirement could be met effectively by the use of suitably located corner reflectors.

Mr. CURTIS (US) added that in the application quoted by Lieutenant Commander McNALLY recent reports indicated that accuracies on the order of 15 yards were being obtained over areas 6 or 7 miles square. He said that the United States Army Engineers were engaged in experiments with shore-based radar at short ranges for the conduct of channel surveys and dredging operations.

Mr. HORTON (UK) asked if the direction finder demonstrated on the Coast Guard Cutter CAMPBELL (the Navy type DAK) were available for merchant ship use and if the performance of the equipment during the recent demonstrations were typical or exceptionally good.

Lieutenant Commander OTTINGER (US) replied that this particular direction finder with its cathode ray presentation was a naval equipment and he believed it to be probably too complex for normal merchant marine use. He felt that instrumental and operator's errors were considerably less with this equipment than those made with the aural null-type direction finder.

Mr. GIRARD (US) added that the lessons learned in the manufacture and use of the instantaneous-indicating type of direction finder had indicated that it would be of great value for commercial service. He said there were no plans for the development or production of the DAK equipment commercially unless a demand for it arose, as he believed that for merchant marine purposes the same result could be obtained in a less complex manner.

Mr. DAVID (France) asked if the cathode ray presentation afforded improved results during night effect.

Mr. GIRARD (US) replied that the cathode ray presentation did not eliminate the night effect but that it did enable the observer to recognize when night effect is occurring. Mr. ROSS (UK) concurred in this statement.

Mr. WANG (China) asked if, now that the delegates had had an opportunity to see the United States commercial radars, the United Kingdom could make available descriptions and specifications for the commercial radars manufactured in the United Kingdom for the benefit of the delegates who had not attended the London IMRAMN.

Sir ROBERT WATSON-WATT (UK) replied that the United Kingdom would be glad to publish a supplement to the International News Letter containing the type of information Mr. WANG requested. He said it would be helpful if delegates would indicate the type of information desired and that efforts would be made to provide it.

Mr. MANSON (Union of South Africa) asked if the United States was proceeding with the development or production of a chart comparison unit.

Lieutenant Commander McNALLY (US) replied that the Navy had a development on it, and Mr. ISBISTER (US) said that the manufacturers were considering it and making plans for it but that there had been, as yet, no great demand for a chart comparison unit.

At this point the Meeting turned to the consideration of the Conclusions, Recommendations, and Views of IMMRAN, which appear in the following chapter. However, at the end of that discussion another technical question was raised, which is included here for convenience.

Mr. MANSON (Union of South Africa) requested information concerning the use of radar for harbor surveillance.

Captain YATES (UK) indicated that complete information on this subject could be found in IMMRAN Document No. 52 (U. K. Paper No. 13) and briefly discussed the highlights of this paper.

Captain HARDING (US) stated that the United States had conducted, and was continuing to conduct, several tests of radar for this purpose, using both 3- and 10-cm. radars, but that the results of these tests had not yet been compiled. Indicating that most United States channels are sufficiently well-buoyed to allow the ship's radar to suffice for channel passage, he stated that the problem was more one of effective communication control than of guiding ships up

channels and that any system of communications control must be universal. He said that tests of VHF D/F and VHF communication were also in progress in this connection.

Commander BURCHELL (Canada) stated that the Canadian Navy operated harbor control radar for 5 years on the east coasts of Canada and Newfoundland and that, in many instances, it had been instrumental in allowing ships to be warned in time to avert disaster. The Canadian National Research Council was at present carrying out extensive trials on this subject at the approaches of Halifax harbor, and it was fully cognizant of the use to which some aspects of Teleran and GCA could be put to increase the efficiency of harbor radar. The policy has been to give information to the ships, but the responsibility for acting upon that information rested with the master of the ship. The Canadian Navy, as a result of its experiences with harbor control radar, was absolutely convinced of its value, and it would be its policy to carry on this work in the future.

CHAPTER V

CONCLUSIONS, RECOMMENDATIONS, AND VIEWS ADOPTED BY THE MEETING

COMMITTEES

At the close of the New York Sessions it had become evident that an international committee or committees would be required to draft the proposals for the conclusions, recommendations, and views of the Meeting and to reconcile any divergences in national viewpoints which existed. Accordingly, the Chairman appointed a Steering Committee for this purpose, which was made up of the following persons:

Dr. William L. Everitt, Chairman
Mr. A. N. Fraser, Canada
Lieutenant Commander Jose Paulo De Albuquerque Guillobel, Brazil
Captain J. Hauptmann-Andersen, Denmark
Mr. M. Loranchet, France
Mr. Denis O'Neill, United Kingdom
Commander K. P. Ryzhkov, Union of Soviet Socialist Republics
Lieutenant Georges Soubassakos, Greece
Mr. A. J. W. van Anrooy, Netherlands
Commodore E. M. Webster, United States
Mr. W. H. T. Wei, China

The Steering Committee appointed three subcommittees, as follows:

Committee A, on all matters pertaining to radar:

Mr. M. Loranchet, France (Chairman)
Mr. A. V. Dubinin, Union of Soviet Socialist Republics
Mr. W. L. Haney, Canada
Mr. C. E. Horton, United Kingdom
Lieutenant Commander I. L. McNally, United States

Committee B, to coordinate problems involving position-fixing systems other than radar:

Mr. Denis O'Neill, United Kingdom
Commissioner E. M. Webster, United States
(No chairman designated)

Committee C, to prepare resolutions on all items not covered by Committees A and B:

Captain J. Hauptmann-Andersen, Denmark (Chairman)
Captain W. H. Coombs, United Kingdom
Mr. W. A. F. Liebert, Netherlands
Captain H. C. Moore, United States
Commander Gilbert V. Parmiter, United Kingdom
Mr. Edward C. Phillips, United States (Secretary)
Commander K. P. Ryzhkov, Union of Soviet Socialist Republics
Lieutenant Georges Soubassakos, Greece
Mr. H. Stanesby, United Kingdom

To facilitate their work, the size of the committees was purposely small. All delegates were invited to submit any proposals they wished to the appropriate committees.

Inasmuch as the delegates were not assembled with plenipotentiary powers, the Conclusions, Recommendations, and Views adopted by the IMMRAN are of an advisory nature and do not represent definite commitments on the parts of the States represented.

After discussions in full session, which occupied the major portion of the final 2 days of IMMRAN, May 8 and 9, the following Conclusions, Recommendations, and Views were adopted.

CONCLUSIONS, RECOMMENDATIONS, AND VIEWS

Preamble

The International Meeting on Marine Radio Aids to Navigation, consisting of the representatives of the States listed below, having assembled in accordance with the invitation of the Government of the United States of America for the purpose of familiarizing themselves with achievements in the field of marine radio aids to navigation, and desiring to assist the respective governments in their individual study and evaluation of the existing radio systems for marine navigational aids and in making such decisions as these governments may consider necessary, adopted the following conclusions, recommendations, and views at its final meeting, held on May 9, 1947.

Argentina	Denmark	Mexico	Union of South Africa
Australia	Ecuador	Netherlands	Union of Soviet Socialist Republics
Belgium	Finland	New Zealand	
Brazil	France	Norway	United Kingdom
Canada	Greece	Poland	United States
Chile	India	Portugal	Uruguay
China	Iran	Siam	Venezuela
Colombia	Italy	Sweden	Yugoslavia

Position Fixing Systems

1. Recommended that development and adoption of equipment and systems for marine navigation should be guided by the following table of desired accuracies and available times for determination of position in relation to the approximate distances off shore and/or depths of water under the keel.

Function	General order of depth of water	Distance from nearest danger	Order of accuracy required	Order of time available to obtain position
Aid to ocean navigation	Over 100 fathoms	Over 50 miles	± 1 percent of distance from danger	15 minutes
Aid to approaching coastal navigation and port approach	20-100 fathoms	Between 50 miles and 3 miles	± 1/2 mile to ± 200 yards	5 minutes to 1/2 minute
Aid to harbor entrance	Up to 20 fathoms	Less than 3 miles	± 50 yards	Instantaneous position and track required

The above recommendation is subject to the proviso that each area has its special characteristics and its own problems, which must receive special consideration within the general framework of the accuracies indicated above, and that, in evaluating specific systems for operational use, cognizance should be taken of other important factors such as proved reliability, search and rescue requirements, economic considerations, etc.

2. Concluded that a position fixing system is required for safe entry into the zone at which radar becomes effective, bearing in mind that the extent of such a zone varies with the adequacy of the radar targets available.

Short Distance Category (Radar)

1. Concluded that high resolution* shipborne radar with ancillary devices, having suitable and approved minimum performance capabilities and operated by qualified personnel, is a device having wide applicability to maritime use for anti-collision, pilotage, above-water obstacle detection, and general position fixing within range of suitable fixed radar targets, either natural or artificial (active and passive).

2. Concluded that a shipborne radar with reduced performance requirements and generally understood to be an anti-collision radar against large ships is completely inadequate for the full requirements for position fixing and navigation in coastal and pilotage waters.

3. (a) Concluded that a universal performance specification for shipborne radar is an essential prerequisite of the compulsory carrying of equipment by certain classes of ships.

(b) Concluded that early action to make the fitting of radar compulsory is not contemplated; this question can be more appropriately examined at a later date.

(c) It is therefore recommended that basic minimum standards, so framed that they will not hamper the developers, be laid down.

4. Recommended that the administrations of the countries in which these apparatus are manufactured should consider the possibility of issuing specifications serving as a temporary guide for the industry and the purchasers of these apparatus.

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* A high resolution radar will have, among other characteristics, the following:

(a) Minimum range. Provide display of a target down to a minimum range of 100 yards.

(b) Bearing resolution. Provide display, as two distinct indications, of targets at the same range separated by not more than 3° in azimuth.

(c) Range resolution. Provide display, as two distinct indications, on the shortest range scale of targets on the same azimuth separated by 100 yards in range.

5. Concluded that a simple and reliable overall performance monitor is an essential requirement.

6. It is strongly recommended that a suitable device be developed to provide accurate and positive identification by radar of navigational markers, dangers, and shore features. It is particularly recommended that reflectors should be installed on selected navigational markers in order to facilitate the differentiation of those markers from other echoes, including sea return.

7. Concluded that a solution to the problem of increasing the echoing efficiencies of small vessels is of immediate importance and that the study of the conditions under which such increased echoing efficiencies should be required on small vessels should be undertaken. Should such study prove successful, it would become desirable that the Conference for Safety of Life at Sea consider the use of such a device.

8. Concluded that a chart comparison unit is a desirable but not essential auxiliary device.

9. Recommended that the Administrations of the various countries should, separately and independently, examine the question of the qualifications required of personnel certificated or licensed to operate or maintain shipborne radar equipment.

10. Recommended that the question of charts for use with radar be coordinated with the chart requirements for other navigational aids.

11. Concluded that shore-based radar has many possible applications to maritime usage and operational trials should continue.

12. It is the opinion of the meeting that the time has not yet come for world standardization restricting shipborne radar to a single frequency band. It is desirable that operational trials continue with shipborne radar operating in the range between 3,000 and 10,000 mc/s.

13. Concluded that a true bearing display is very desirable but not indispensable.

Short and Medium Distance Category

1. Concluded that the system of MF/DF and associated radiobeacons, although it may not fully satisfy the requirements set out in the table referred to in recommendation 1 of Position Fixing Systems, can continue to fulfill a useful function in making landfall and in coastal navigation and for search and rescue requirements.

The system should be periodically reviewed in comparison with the then existing needs of the marine user in regard to coastal areas.

2. Concluded that the existing systems of radiobeacons provided for use in conjunction with shipborne MF/DF should be maintained universally at a standard not below that at present provided and that in certain areas, notably those where such systems are established, they should be improved and expanded.

3. Concluded that Decca, provided that it continues to give operational satisfaction and that the application of lane identification proves effective, appears to provide a position fixing system of an accuracy which meets the mariner's requirements and therefore should be improved and expanded in regions where the nations concerned consider it desirable.

Long Distance Category

1. Concluded that a long range navigational aid, while desirable for certain marine services, cannot be regarded as having the same priority as medium distance navigational aids. The long range aid requirements of aviation are the more pressing, but in determining the most appropriate long range aeronautical aid it will be to the mutual advantage of both air and marine interests if due weight is given by the former to the relative advantages of the different long range aid systems from the marine point of view.

2. Concluded that if the effective coverage area of a system be taken as that within which the system gives a usable signal to noise ratio, Standard Loran gives higher accuracy within its effective coverage area than does Consol within its larger effective coverage area. There, as a long range navigation system, Standard Loran should be continued and improved and should be expanded wherever it can jointly serve both marine and aviation to mutual advantage, with the agreement of the nations concerned.

General

1. Recommended that participating delegations should communicate to their national delegations to the International Telecommunications Conference these conclusions on the operational and technical merits of the systems reviewed above, it being understood that these very important frequency requirements for radio aids to marine navigation must be considered by the forthcoming International Telecommunications Conference in relation to other pressing demands on an already over-crowded spectrum.

2. Recommended that, in view of the importance of radio aids to safe marine navigation, adequate provision should be made to

meet the requirements of mariners at the forthcoming International Telecommunications Conference.

3. Recommended that, for the purpose of making information available to the user upon request and to have such information available for an appropriate future international conference or organization, an international standing committee be set up comprising scientific experts to obtain and coordinate numerical data on the performance of various radio navigational aids and that, if a future appropriate international body should establish an organization appropriate for the continuance of such work, the functions and data accumulated by the standing committee should be absorbed by such international organization.

The Meeting therefore invites the Governments of the United States and the United Kingdom jointly to study the means of implementing the above recommendations.

4. Recommended that each administration undertake or continue studies and analyses and prepare proposed minimum standards for radio aids to navigation equipment other than radar.

5. Recommended that each Administration ensure the institution of an adequate personnel training program for efficient operation and maintenance of radio aids to navigation equipment.

6. The Meeting is of the opinion that it is desirable that the tolerance of components and the design of equipment should be such that when components are interchanged no realignments become necessary which would require special apparatus of skilled personnel.

7. This Meeting is of the opinion that it is desirable that arrangements be made to standardize the dimensions and electrical characteristics of the main components (such as magnetrons, local oscillators, crystals, tubes, transformers, etc.).

8. It is the opinion of the Meeting that VHF radio telephony will provide the maritime service with a valuable means of navigational communication for ship to ship and ship to shore, within the range allowed by the choice of frequency.

Requirements of the maritime service for harbor control of shipping, safety, distress, and navigational communications on rivers and lakes as well as on the coasts of the various countries suggest that at least one two-way circuit in the 150-160 megacycle region should be adopted as standard. There should also be international standardization respecting the type of modulation to be employed and the characteristics thereof.

If it proves desirable to standardize on two frequencies for this purpose, consideration should be given to the possibility of separating them by some difference, such as 5 mc.

It is therefore recommended that international agreement should be secured on the allocation of frequencies for at least one two-way communication circuit and that, if possible, further allocations should be agreed internationally for a second such circuit, should the first prove to be insufficient in the vicinity of 160 mcs.*

9. Recommended that each country establish appropriate machinery to coordinate air and marine interests so that delegates to international meetings on either marine or air radio aids may speak with the interests of both in mind.

10. This Meeting is of the opinion that no monopolistic practices should prevent any country from manufacturing radio aids to navigation that have been agreed internationally as of proved value to the mariner.

CONTROVERSIAL POINTS

The procedure followed in the Meeting was such as to allow the adoption of only those Conclusions, Recommendations, and Views on which complete unanimity of opinion prevailed. The sole exception to this rule is the recorded minority dissent of the Union of Soviet Socialist Republics Delegation on the question of VHF radio telephony. Under such a procedure, no resolutions concerning questions on which there were widespread differences of opinion

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* The Union of Soviet Socialist Republics Delegation did not fully support item 8 and requested that the following statement be appended to indicate the scope of disagreement and support:

> "The Delegation of the U.S.S.R. considers that VHF radio telephone communication systems are important only as local navigational aids and do not have international significance at the present time. Therefore, the Delegation of the U.S.S.R. considers that the time has not come yet to accept any detailed recommendation on this matter and feels that the resolution should contain only the following statement:
>
> "'It is the opinion of the meeting that VHF radio telephone will provide the maritime service with a valuable means of navigational communication for ship to ship and ship to shore within the range allowed by the choice of frequency.'"

appear in the final Conclusions, Recommendations, and Views of IMMRAN. For this reason the following paragraphs attempt to show the major points of discussion on which no final statements were adopted and to show the divergences of opinion on points where compromise agreements were reached.

The subject on which there was probably the greatest controversy was that of type-certification of radar and other radio aids to navigation. Committee C first submitted the following recommendation for the consideration of the Meeting:

> "It is recommended that the Administrations of the countries in which radar is manufactured should issue, when required, type approval certificates indicating that the equipment type complies with the prescribed specification as determined by official type test approval."

Committee A submitted the following similar proposal with respect to aids to navigation other than radar:

> "It is recommended that type approval of radio aids to marine navigation and the inspection and licensing of individual installations is essential."

In both instances the United States Delegation dissented with the proposals, and both were referred to their committees for further consideration and an attempt to arrive at a compromise proposal. The two committees jointly considered the problem and proposed the following resolution, which combined the two separate recommendations but did not alter the essence of either:

> "It is recommended that the administrations of the countries in which radar and other radio aids to navigation are manufactured should issue, when required, type approval certificates indicating that the equipment type complies with the prescribed specification as determined by official type test approval."

Again, the United States dissented and, having been requested earlier to submit their reasons for dissent, submitted the following statement:

> "The United States Delegation dissents because we feel that government type-approval certification, at this time, would not guarantee to the purchaser that he was receiving a completely adequate and reliable equipment. We feel that the development of maritime shipborne radar systems has not reached the advanced state where the manufacturer and the mariner can set up exact requirements. Commercial radar is only a few

months old, and already we have learned many valuable lessons. The government is not qualified, at present, to determine performance specifications which would be used to certify that a given type of radar meets the mariner's requirements. The quality of product demonstrated to you in the past week should assure the purchaser that our system of free enterprise in competition will result in the best and most reliable equipment possible for the mariner, incorporating exactly what he desires and not just barely meeting a set of government requirements. If at some future date action is taken to make the fitting of radar compulsory, the government could not invoke any specifications other than the standard that it required today. If it did, it would condemn all equipment previously guaranteed, thereby destroying confidence in all future approval it might guarantee. Improvement and development would not be as rapid or beneficial to the mariner because industry could standardize on the cheapest set which met the requirements which were laid down before we knew what the requirements were. Do you think, if we exercised government control over the depth finder in its early stages of development, that we would have a device possessing such a high stage of perfection today that it is as much a part of the ship as the engines? Demonstrated performance, service, reliability, guarantee, and good reputation, not to be jeopardized by an inferior product, are much more difficult to establish and earn than a certificate indicating government type-approval."

The United Kingdom had steadfastly supported the original form of the resolutions on this subject. Their position is shown by the following words of Sir ROBERT WATSON-WATT:

"We in the United Kingdom take a much more kindly view of the influence which government can have in improving standards by type approval of the kind which can be pegged up as the art progresses. We do not believe that type approval has validity for a long time. We are perfectly prepared to revise our standard to fit good practice. We see no administrative difficulty in permitting the continued use of previously type-approved devices for a period after type-proven standards have gone up."

Since the Committees had failed to resolve the essential difference in viewpoints, the matter was put to the vote of the Meeting. Argentina, Australia, Brazil, Canada, Chile, France, India, New Zealand, Norway, Poland, Portugal, Siam, Union of South Africa, Union of Soviet Socialist Republics, the United Kingdom, Uruguay, and Yugoslavia favored the final resolution as proposed by the Committees.

China, Denmark, Finland, Greece, Iran, Italy, Mexico, the Netherlands, Sweden, the United States, and Venezuela opposed the recommendation.

After some discussion it was agreed that the lack of unanimity precluded the adoption of the recommendation, or any other recommendation on the subject, by the Meeting.

There was also dissension to a conclusion that a true bearing display on radar equipment was not essential. The United Kingdom, supported by representatives of Denmark, Portugal, and the Netherlands, contended that a true bearing display is essential; while the United States and France felt that it was not necessarily essential but more a matter of individual choice and suitability for specific operations. The proponents of this viewpoint argued that standardization on true bearing indication alone might force unwanted standardization upon certain ship operators for whom the relative display is better suited. There was a general feeling that both true and relative displays each have a definite scope of preferability, depending upon individual circumstances. This controversy was finally resolved by rephrasing the conclusion to state that true bearing indication is very desirable but not indispensable.

The Union of Soviet Socialist Republics did not fully support the opinion of the Meeting concerning VHF radio telephony. The scope of their dissent and support is indicated in the Conclusions, Recommendations, and Views.

STATEMENT OF THE NETHERLANDS DELEGATION

The Netherlands Delegation introduced the following statement for inclusion in the proceedings:

> "The accuracy required for approaching and coastal navigation (50 to 3 miles) is stated in the Conclusion under Position Fixing Systems as one-half mile to 200 yards.
>
> "We fully agree with this recommended accuracy but should like to draw attention to the fact that, as far as regards shoals and other dangers to navigation lying out of sight from land, the charted position of such dangers is not always accurate to within one-half mile.
>
> "So, in several cases it will be necessary that new hydrographic surveys be undertaken with a standard of accuracy sufficient to meet the requirements mentioned in the Conclusion and possible future requirements.

"Such new surveys, hydrographic as well as aerial, at present and in the future will make use of position-fixing systems of high precision.

"So we make the following statements:

"1. It is recommended that such steps be undertaken by the Hydrographic Departments of all countries concerned that nautical charts be sufficiently accurate to meet the requirements in the Conclusion.

"2. It is recommended that operation trials with precision position-fixing systems, suitable for all kinds of survey work, be continued."

CHAPTER VI

CLOSING SESSION

Chairman: We come to the final session, and again I will try to summarize the accomplishments that we have achieved during this week. I think that the committees who have met and have worked so hard during the week have made the real accomplishments, for which we are all very grateful.

Last week I attempted in my summary to point out the points of difference and the points of agreement. To quite an extent some of those disagreements have now disappeared and are indicated in the resolutions which we have produced. I think we must recognize that this has not been a problem of merely coordinating the differences of opinion between the different countries, but that it has been a problem of obtaining unity for the group representing marine interests. Thus, in the future, as we discuss our problems with those primarily interested in the air and also with the users of the universal frequency spectrum, we will have a unanimity which will help us in securing adequate use of radio aids for the marine navigator.

It is evident that the final answer to our problem is coordination and not conflict. There has been, where there is a difference of opinion, a decided give and take, a desire for coordination and for compromise, rather than for conflict, which I think we have all seen in the results yesterday and today.

There has been universal agreement that there is not a desire on the part of any country to set up a monopolistic control, and I believe that the spirit that is indicated there means even more than the specific statements that were made. We have, I believe, secured recommendations which will have an impact as they are passed on to the delegations of forthcoming Meetings, where final decisions must be reached and where the power is available to reach such decisions. The fact that we have been able in an informal manner to reach conclusions should indicate great hope for definite decisions at the various conferences which are scheduled for the coming year.

In the matter of specific determinations, we have recognized that the high resolution radar is important. I think in several cases we have gone quite far into some of the details, and I believe that this is desirable. I think that when a group can go quite far into some specific details it indicates an even greater spirit of

cooperation than when the resolutions must be phrased in innocuous terms. I think we have generally agreed that a cheap radar is not useful and, in fact, might even be dangerous. Furthermore, there probably is no such thing as a cheap radar, since the cost which would be saved in manufacture or in the purchase might well be lost in operation. We have emphasized the need for specifications, and I believe that, as a result of this universal desire for more detailed specifications, they will be forthcoming on all types of apparatus.

It has been indicated that there is a high desire for the provision of monitoring equipment. I might mention in terms of my own experience that I have found that when it comes to actual operations, simple effective tests that can be made on the job are the most important means of securing adequate maintenance.

We have discussed to quite an extent the problem of the small vessel, but it is quite possible that more should be done in that area. The qualifications and the training of personnel have been emphasized for both radar and for other radio aids to navigation; and again those of us who have been engaged in the past in the introduction of new electronic devices know from experience that adequate training is as vital, or perhaps more vital, than adequate design of the equipment itself, although the design must precede the training.

We have decided that the time is not yet ripe to standardize on microwave frequencies but have left open the way for further operational studies and the obtaining of sufficient experience before final decisions are made.

In the matter of pilotage, we have reiterated the table of last year but have recognized the need for the provision for the solution of special problems. We notice that position fixing is necessary in order to guide the ship into the area where radar should take over. MF/DF and beacons have been recommended as a continuing aid, and we have recommended that improvement in these is desirable wherever possible. We have recognized not only that they are a navigational aid but that MF/DF direction finders have a very important bearing upon the problem of rescue.

Agreement has been reached that Decca, if it shows the performance indicated by the promise of the papers that have been presented, should be improved and expanded in the regions where the nations consider it desirable.

It has been agreed that long range navigational aids are important but that the problems of the air are the most pressing.

It is further agreed that Loran should be continued and improved and expanded, particularly where the air and the sea jointly have needs for navigational systems. You might, therefore, expect that further discussion on this would take place in other conferences.

I think we have, in the reports of other committees on which we have taken action, agreed that we must go ahead on standards and on standardization. These two items are sometimes confused. Standards help us to determine the design and the methods by which the equipment should be presented, while standardization will help us greatly in the problem of maintenance and in converting personnel from the use of one type of equipment to another or from one ship to another.

We have recognized that VHF is an important ally and that communication generally, as well as the aids that we have discussed in more detail, must be developed further.

This resume, of course, is very brief and covers only some of the most outstanding items, but I am sure that as you read these resolutions in more detail and go over them you will feel, as I do, that we have a sense of accomplishment in the results that have been obtained. I hope also that you have enjoyed the opportunity to see American equipment in operation. In fact, many of you have had the opportunity to find out just how easy it is to learn to use some of these new electronic aids.

I do not know of any group of people I have enjoyed working with more than the group that has been here together during the past week. I have been amazed at your close attention as we have presented to you eight papers or more a day. It is, I must admit, somewhat better than I can expect from most of my college students, but that may be because the lecturers were so much more able.

In that connection I might mention a circumstance that I once had where I had a student who repeatedly went to sleep. I finally decided I would have to teach him a lesson so I wandered down, talking all the time. As I came up close to him, I suddenly said: "Everybody who is a big fool stand up." He jumped right up to his feet and looked all around and said, "Well, professor, I don't know what we are voting on, but you and I seem to be in the minority."

We have had a few majorities and a few minorities in our discussions, but we note that, of the recommendations that were brought in, we finally were able to compose our differences in some respect on every item.

Again I want to thank all of you for working with the American delegation, with the American Secretariat, with all of the various

groups that have been in contact with you; and I hope that we may all see you together again sometime in the future. Thank you very much.

Sir ROBERT WATSON-WATT (UK): Mr. Chairman, Delegates, there remains one requirement which is not only very desirable but is, indeed, indispensable, and I think I can assure you of the completest unanimity amongst your students on this issue. To you, President Bill, we would like to say that you have been the kindliest, most tolerant, and most helpful of supervisors. Sitting in your class has been almost painless, and the happiness of sitting at your feet is not diminished by the fact that there are no examination papers impending.

We would like, through you, to offer our thanks to the 300 or more people who, in the first line, have made this Conference the indubitable success that it has been.

I have on this, as on another occasion, the somewhat onerous distinction of speaking the language of every delegation present. I have been invited by your visiting delegations to speak for them, not because I speak their languages, but, presumably, because they are convinced that I will go on speaking whether they ask me to or not. But I assure you, Sir, that I know what is in their hearts and, if I can only express it inadequately, I will still regard it as one of the greatest privileges of my participation in this Conference, that I am allowed to speak from their hearts.

We thank the Chairman and members of the committees who have worked incessantly under grave difficulties, due to the impossibility of taking time off from the attractive entertainments that would get in the way of committee meetings.

We are grateful to the Captains and crews of the ships who taught us so much about the needs and the possibilities of the radio navigational aids that we have been discussing.

We are grateful to the industry exhibitors, who were models of technical integrity and who took a very enlightened view of their individual responsibilities. I met a number of them who were quite clearly selling their competitors goods, sometimes inadvertently, but on the whole generally by conviction that the goods were good and that it was more important that they should be good than that they should bear a particular nameplate.

To our hosts—our hosts in New York City, on the ships, and in this beautiful architectural monument, this erudite and versatile Academy—to all these people we have debts of gratitude which we hope to repay never in full but in part when we meet in much the same groups in other countries.

It is one of the happy features of our kind of international negotiations that we grow a kind of family tie in which, after 2 years, after 4 years, sometimes after 10 years, we find ourselves in another country but in the same grouping of minds and friendships and Christian names, that encourages us to believe that the world is an even smaller place than it is being made by radio communications.

But we should do wrong if we didn't offer thanks to our good selves. We, the delegates, have a creditable record. We have worked hard; we have played hard; we have devoted a great part of the 25 hours to the adjustments of view that can only be worked out in informal discussions and in small, isolated parties; and I believe we have the right to claim that we have been something by way of being models of accommodation of view. There has been on no side of this conference a tenacity of view which refused to yield to the evidence and to the arguments which have been brought to bear on each of our individual subjects.

When we look at that Sperry subsidiary at Lake Success which calls itself the United Nations, we know that we have no right to compare our achievements with their's. We admit that we have attempted the difficult; their attempt on the almost impossible will take a little longer. But I think they might well have a look at our proceedings and see that there is, indeed, high hope for international agreement on complicated and difficult subjects.

And to the Secretariat, I would like to speak in the name of all of us with special warmth and with special thanks. The Executive Secretary has a right to be proud of the perfectly-operating team which has made our lives so easy. Alike in documentation, in logistics, and in psychology they have been perfect; they have passed with high honors. The documentation problem is one which makes and very frequently mars a conference, but I know of no conference in which the documentation has flowed so smoothly, so expeditiously, and so accurately as this second international meeting.

I would ask to be allowed to move, in general terms--but to leave to the Editing Committee the work of putting exact words to the general terms--a resolution of cordial thanks and gratitude to our United States hosts. We would ask that our thanks also be formally recorded and conveyed to each individual member of the Secretariat who has made this international meeting a success and a notable step forward in the progress of radio aids to navigation.

Mr. CROSS (US): Mr. Chairman: I have no prepared talk because until a short time back I didn't know just how we were going to come out of this. I didn't have time to write two kinds of talks. Following after the very excellent speech which Sir Robert just

gave is a most difficult task, indeed, because he can go around me like a hoop around a barrel when it comes to talking. I have found that out. So I am somewhat like the man who was touring through Hannibal, Missouri, the home town of our Samuel Clemens, the famous Mark Twain. He ran across an old-timer of the village, and he asked, "Did you know Mark Twain?" This fellow, with a snort of contempt, said, "Yes, sure I knew him, and not only that, I knew just as many stories as he did. The only thing was, I didn't write mine down." So I haven't written mine down.

We are, indeed, glad here in the United States to have so many of you present.

Secretary Norton, in his opening address, asked for your active participation in this meeting, and I am certainly grateful to all of you for the time and effort that you have put into it. I shall report to him with great pleasure that the meeting not only was a very active one but that, in my opinion, we accomplished much. I think the aim of the meeting, as we set it forth in the opening remarks, has been accomplished.

We had a statement that if any fruitful conclusions were reached they would be recorded and passed along for future reference and utilization when the nations of the world meet to consider standardization of equipment in this field. I think we have reached many fruitful conclusions, recommendations, and opinions that will serve as guideposts to those who follow us in this standardization of radio aids to marine navigation.

To the Chairman, for his splendid conduct of this meeting, the heartfelt thanks of myself, as Executive Secretary, and of my colleagues on the United States Delegation.

To the Secretariat, you have been a wonderful group to work with and, as your Executive Secretary, I am very proud of you, one and all. You have made this a smooth-running and efficient meeting and have taken full account of the well-being of our guests. I think you have done splendidly and I thank you.

To the industrial representatives of the United States, without whose cooperation it would have been impossible to conduct a meeting such as we have had, my thanks again. You have been a "grand gang" to work with, and I can hope for nothing better than the pleasure of having you with us again at some future time.

Last, but not least, to the Officers and personnel of the Coast Guard, for the wonderful way in which they have taken care of us since we have been here, my heartfelt thanks--and that goes for all of the United States Delegation, of course.

Again, it has been a great pleasure to have had you all here. I want to wish you a safe passage home and hope that when you arrive there your administrations will be pleased with the results of your productive work here and that our collective efforts will result in providing the mariner with a better means to take his ship safely over the oceans of the world. Thank you very much.

Chairman: Thank you again for your cooperation. Goodbye and good luck. The meeting is adjourned.

PART TWO

Technical Papers

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN · · · APRIL 28-MAY 9, 1947

UNITED STATES POLICY FOR RADIO AND ELECTRONIC AIDS FOR MARINE NAVIGATION

The national security, the nation's sea commerce, and the assurance of adequate safety of life and property at sea require an efficient, integrated, standardized system of radio and electronic aids for marine navigation.

A multiplicity of new radio and electronic devices and systems possessing potential applicability for marine navigation have been developed during recent years, both at home and abroad. In fact, the devices and systems which have been developed and made potentially available as aids to navigation are so numerous that standardization is mandatory if the encouragement and development of United States sea commerce is to take place economically and realistically.

In consequence, it is vital to the national interest that the United States play a leading role in the development, investigation, selection and standardization of a world-wide system for marine navigation. This role should be played at the earliest practicable moment consistent with open-mindedness and sound technical judgment directed toward the attainment of optimum results, with due consideration for the cost to ship operators being kept as low as practicable.

An open-minded attitude shall be maintained toward novel systems and devices which eventually may develop to be superior to existing systems. This attitude, however, shall not be permitted to retard the adoption of a world system based on systems already proved and in wide use over a large part of the world's waterways.

To simplify standardization, to effect the greatest economy in operation and to further the most economical use of the radio spectrum, the joint use of radio aids by both air and sea craft is hereby advocated where mutually advantageous.

The policy contained herein is applicable for domestic guidance as well as for use as a basis for international discussions on standardization of devices, systems and performance.

For the present and at least the immediate future the following devices and systems are advocated as being practicable

I. <u>Navigation</u>

A. Anti-Collision.

The use of radar shall be encouraged in order to enhance safe and economical operation primarily to reduce the risk of collision.

B. Position Fixing.

1. Distances over fifty miles.

(Aid to ocean navigation requiring accuracy of 1% and allowing 15 minutes to obtain position fix.)

(a) Loran - This system shall be continued, improved and expanded.

(b) Shipboard MF/DF with radiobeacons (useful up to 200 miles). This system shall be continued, improved and expanded.

2. Distances between 50 and 3 miles.

(Aid to approaching land, coastal navigation and port approach requiring one-half mile to 200 yards accuracy and allowing 5 minutes to one-half minute respectively to obtain position fix.)

(a) Shipboard MF/DF with radiobeacons. This system shall be continued, improved and expanded.

(b) Shipboard radars. Their use shall be encouraged and the devices shall be improved.

(c) Radar aids, both active and passive. They are necessary for the special marking of navigational aids, dangers and shore features,

to facilitate identification by radar. Their further development for purposes of operational evaluation should be continued.

3. Distances less than 3 miles.

(Aid to harbor entrance requiring 50 yards accuracy and instantaneous position and track fixing.)

(a) Shipboard radars (high resolution). Their use should be encouraged and the devices shall be improved.

(b) Radar aids, both active and passive. They are necessary for the special marking of navigational aids, dangers and shore features, to facilitate identification by radar. Their further development for purposes of operational evaluation should be continued.

(c) Shipboard MF/DF with radiobeacons. This system shall be continued, improved and expanded.

II. <u>Harbor Control and Harbor Communication</u>.

A. Harbor Control Radar.

This service shall be provided as required.

B. Harbor Control Communications.

VHF Radiotelephone channels for harbor control purposes shall be provided. The channels and modulation should be standardized internationally.

III. <u>Frequencies</u>.

The United States shall advocate the international standardization of frequency allocations for use or operational evaluation with respect to the above devices and systems.

It is believed that the frequency allocations recommended to the Department of State by the Interdepartmental Radio Advisory Committee and the Federal Communications Commission will meet the operational and technical requirements of the radio

navigational devices and systems herein designated. These are as follows:

A.	Shipboard Radar:	3000 to 3246 Mc
		5460 to 5650 Mc
		9320 to 9500 Mc
B.	Radar Beacons:	3256 Mcs ± 10 Mc
		5450 Mcs ± 10 Mc
		9310 Mcs ± 10 Mc
C.	Loran:	1800 to 2000 kc
D.	LF/MF Radiobeacons	280 to 320 kc
E.	Harbor Control Communications in the Band:	152 to 162 Mc

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN · · · APRIL 28-MAY 9, 1947

WORLD RADIO AIDS TO NAVIGATION

- By -

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ABSTRACT

This paper presents a short summary of events leading to the United States International Meeting on Marine Radio Aids to Navigation, including a review of recent developments in the field of international Radio Aids to Marine Navigation. The trade routes of the world are outlined along with some estimate as to the needs for Radio Navigational Aids on the routes. A philosophy of Aids to Navigation is developed and some of the pertinent characteristics of a lasting aid are pointed out.

WORLD RADIO AIDS TO NAVIGATION

Mr. Chairman, Ladies and Gentlemen:

1. You have heard this morning from those gentlemen who are concerned with the ceremonial and administrative aspects of this meeting. It is now time that we begin to study the general and practical consideration of Radio Aids to Marine Navigation. In some phases of this subject I feel particularly well at home as I note from the list of delegates and speakers the names of many of my former students or shipmates as well as those of old colleagues with whom I have been associated in other international commercial and government meetings.

2. Last May, in London, the discussion of international radio aids to marine navigation was opened. Everyone recognized the importance of and the need for international agreement on certain aspects of the problem. Some took the view that we should, at that time, record conclusions, recommendations and resolutions. Some, particularly those who had been denied the opportunity of participating in progress made during the war, attended to listen and learn, while others took the position that it was premature technically and unsound economically to set standards for marine radio aids to navigation at that time and as a result of that meeting alone. The end result was that the London meeting served to introduce basic systems and ideas, to emphasize the absolute need for a set of operational standards against which all radio navigational systems could be examined in the same perspective; but no definite commitments, resolutions or standardizations were accomplished. The Ministry of Transport of the United Kingdom took up the task, as assigned by the London Meeting, of keeping interested governments informed of world progress in radio aids to navigation.

3. Here in the United States we have completed one operational research test of radar on the Great Lakes about which you will hear in a later paper. We have accumulated more complete information on the behavior of radar on the Grand Banks off Newfoundland and the ice fields of the North Atlantic. We have conducted numerous individual operational tests of commercial radars. We have examined critically the problem of fixed radar aids and have arrived at some definite conclusions regarding this apparatus and its use. We have worked toward improvement of the radiobeacon system particularly pointing to use by automatic radio direction finders on both air and surface craft. Our United States manufacturers have arrived at production models of commercial shipboard Loran equipment following the general scheme of other radio aids -- that is, some models are elaborate and

almost fully automatic whereas other models, at a sacrifice of convenience, have appeared in the lower cost ranges.

4. The Provisional International Civil Aviation Organization (PICAO) has selected low frequency Loran as the system most likely to meet the operational requirements of a long distance radio aid for air navigation and regional PICAO conferences have generally indicated that standard Loran, as presently installed, is required for interim use as a long distance air aid pending the development of a system or method that will fulfill more adequately the needs for long distance air navigation.

5. Before any consideration can be given to world radio aids to marine navigation we must critically examine the main trade routes of the world, ever bearing in mind for the sake of economy and efficiency that a marine system for surface use should also serve the needs of over-water air navigation. Some restrictions must be placed on this aspect of the problem. The requirements for terminal facilities for air navigation are so divergent from the requirements of terminal facilities of surface navigation that it will be impossible to integrate the two into a common system. Beyond the terminals, however, from coastal departure out and over the open sea, the requirements of air and surface navigation are sufficiently common as to give considerable hope of integration to a common system.

6. Some parts of the picture of postwar world trade routes are immediately clear. The traditional North Atlantic route is probably the most predominant in traffic as well as the most hazardous. The air routes here in general follow the surface routes trending somewhat to the northward to take advantage of land bases to shorten required over water distances between terminals. To complete the Atlantic picture we find a concentration of surface routes from Europe to the east coast of South America and from North America to the East and West coasts of Africa. Incidentally, we most assuredly expect traffic on these routes to increase. Merging with these routes, particularly on the southern portions of each, we find traffic lanes from the east coast of the United States to Central and South America and from the West Coast of Europe to Africa. The air lanes on these routes follow principally the coast lines of the Americas and the Europe African coast lines. Here point to point medium distance aids can be provided for air navigation -- and as the weather is in general good, the need for long distance over water aids is somewhat diminished.

7. In the Pacific we find the surface routes concentrating from the West Coast of the Americas to the Hawaiian Islands. The air routes of the Central Pacific run from the West Coast of the United States to these same Islands. Here long distance over water aids are

progress in the art of transportation during the last war has produced an increase of 30 to 40% in transportation speed, an increase of 25 or 30% in individual ship capacity and an increase of 15 to 20% in operating economy. To be useful and successful, the post-war world navigational aid system must harmonize with and fit into this progressive aspect of marine transportation and must also reflect ultimately an economy to industry in the form of more efficient, reliable and safer operation.

13. We must be aware of the fact that from a technical standpoint we have a fairly limited and definite electronic educational level among our ship operating personnel. During the last war we developed emergency methods for the training of personnel which necessarily did not include a complete and well-rounded technical foundation, but by the nature of the emergency were limited to a few knacks or tricks of operation to secure immediate results. A navigation aid or device to be acceptable and useful must provide the necessary data in proper form to enable the operating personnel to take the craft where and when they choose under all weather conditions. This requires that the design of the device or system provide for a maximum use of the principle of transfer of skill, that is, a large part of the highly technical and skilled aspects of the problem must be performed ashore where specially trained technical personnel are available and the device or system must provide the medium for transferring the bulk of technical accomplishments to lesser trained personnel who operate the equipment aboard the ship.

14. We must guard against the natural and popular notion that new devices will immediately make obsolete all devices now in use. Actually most devices begin to become obsolescent the day that they are installed, but it is many years before the general practical navigator has exhausted all the possibilities of any navigational system or device. The mariner is particularly slow, and rightly so, in discarding those methods and means that have for years served to assist him in consummating a safe voyage. He will not accept or even use new devices or systems until they have been completely proven and reliably provided to the extent that they become an everyday part of his navigational routine.

15. I would like to develop what might be called a philosophy of aids to navigation. This can be done by examining carefully the universally accepted aid to navigation that has survived the test of time. Undoubtedly the old lighthouse is the most universally used aid and in fact is the cornerstone of all our aids to navigation systems. What particular characteristics of this aid have served to place it in this position? First, it speaks an international language understandable by all who approach it, or in other terms, it is standardized internationally. It is permanently located and

accurately operated. It is reliable and simple to use. Its reliability can be checked easily and the accuracy of information obtained from it is _solely dependent on the characteristics of the instruments carried on the vessel which has need for the information_. This is tremendously important for two reasons: the responsibility for accuracy of information lies, without question, solely with the individual obtaining and using the information and secondly, it serves as a continued challenge to the navigator to perfect his _own_ ability and equipment. Furthermore, the popularity of the lighthouse is enhanced by its very personality as the voice of a friend is recognized or the charms of its characteristics are observed. In its unobtrusive way it is always there and even if previously ignored can be used immediately as the need arises. In other words, it does not require a previous record or continual observation in order to make it available for immediate use. The navigator does not have to make an official demand, couched in a prescribed form, for information. It is his for the taking. For example, the old _shore-based_ radio direction finder, now obsolete in the United States, required that the user wait in line for his turn, then it demanded that the request be submitted in a prescribed form and even more, the user had absolutely no way of knowing the extent of reliability of the data provided other than a blind trust in shore personnel and an occasional curt warning "bearing doubtful." The lighthouse is the ideal representative of a democracy, absolutely free of any annoying prerequisites, and a constant inspiration for individual perfection and accomplishment. Its cost of operation and technical requirements for personnel are a minimum. We might well review any specifications for world radio aids to marine navigation in this light.

16. Summarizing and interpreting world radio aids to navigation in the light of foregoing discussions, it is clear that surface vessel terminal navigational aids have little in common with air navigation and are of sufficient merit to be considered from the shipboard standpoint alone. Fortunately the commonly accepted terminal and short distance shipboard navigational devices are in addition excellent safety at sea devices as well. Further, they are in many ways independent of international decisions other than that of frequency considerations. Any system advocated for navigation use in this range must be unique indeed if it is to replace one of these dual purpose devices. Unfortunately as we proceed from short to medium distance aids we become more and more dependent on shore based equipment as an adjunct to shipboard devices and at the same time are forced into the field of single purposed equipments. It then becomes clear that both international agreement and coordination are imperatively necessary. As government economic considerations will naturally limit the provision of long distance shore based aids, some priority will have to be arranged. It seems natural to consider the most hazardous and most frequently used routes first. It is

important to bear in mind that any system provided over a priority area should be so standardized and agreed to as to permit a ready extension of the system through regional agreements as economic conditions permit and as are required by future developments, such as the Safety at Sea Conference.

17. It is extremely unlikely that the requirements of either air or surface navigation taken alone will justify a long range navigational aid system, but both taken collectively amply justify this requirement in certain areas and either air or surface interests would be extremely foolish to proceed on a system independent of the other. Overall we collectively have a definite need for a long distance all weather marine navigational aid for air and surface craft, one that is universally accepted, one that is capable of extension and expansion as the need arises and one that is standardized so as to be universally understood throughout the world.

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INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN · · · APRIL 28-MAY 9, 1947

FREQUENCY BANDS AND THEIR UTILIZATION FOR MARINE RADIO AIDS TO NAVIGATION

- By -

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April 28, 1947

ABSTRACT

This paper offers a broad and objective outline of the frequency service-allocations being proposed by the United States to the International Telecommunications Conference for the maritime navigational service. Joint use of facilities by marine and aviation services, where practicable, is advocated.

Salient features of systems and equipments to be utilized in the proposed navigational bands are touched on.

Necessity for world agreement on the standardization of navigational systems and appropriate frequency service-allocations is stressed.

FREQUENCY BANDS AND THEIR UTILIZATION FOR MARINE RADIO AIDS TO NAVIGATION

Introductory

1. Far-reaching advances in the art of radio in recent years compel our reappraisal of frequency band allocations for marine radio aids to navigation, both present and future.

2. The imminence of the International Telecommunications Conference in Atlantic City next month lends timeliness and appropriateness to a discussion of the subject at this Meeting.

3. Ever since man has gone down to the sea in ships, he has sought the perfect navigational system. He seeks a system which will permit him to travel from one port to another, over the shortest track, in the fastest time, consistent with safety. He still seeks that perfect system.

4. In the meantime the true navigator uses every aid at his disposal, though imperfect, to show where he is, where he is headed, what his ground speed is, and what dangers lurk in his vicinity. One of these aids is radio.

5. Your presence here is ample recognition of the value of radio aids to marine navigation, present and potential. You are here to simplify the mariner's navigational problem, if not to solve it, by the application of radio.

6. But, unfortunately, you cannot use radio without using frequencies. I say "unfortunately" because today the service-allocation of frequencies is highly complex. At the time of Cairo, 1938, only a few types of navigational aids were in use. These were operated largely on a regional basis and thus did not present a difficult problem in so far as frequency allocations are concerned. Today, however, the situation is vastly different. During the recent war, numerous new navigational aids were developed. Most of them were designed around specific frequencies inherently built into the devices in such a way as to preclude a shift of frequency. These over-all advancements during the war -- in knowledge of techniques, radio frequency generation, microwave phenomena and the engineering of systems required for the successful application of these advancements to the field of radio aids to navigation -- represent perhaps from ten to twenty years peacetime progress and heavy financial investment.

7. The United States recognized, even during the war, the impact

these devices might have on the frequency allocation table. In consequence, we undertook special studies of the problem to evaluate those aids which might lend themselves to peacetime application for the marine and aviation services. The task has not been an easy one, nor has it been completed. Many devices have been discarded altogether. Others have reached an advanced stage of development. Others are in trial service to demonstrate their ultimate worth. Those selected are now providing navigational service and thus additional safety to both ships and aircraft. The dual service feature is in complete accord with the United States view that, whenever practicable, in the interest of frequency and equipment economy, the same aids should be employed jointly by ships and aircraft.

8. Toward obtaining the views of other countries, the United States has participated in numerous fruitful international discussions, demonstrations, conferences, and meetings on the general subject of standardization of radio aids to navigation.

9. The United States considers that standardization of navigational aids is essential.

10. There are two major reasons for this. Ships and aircraft cannot carry the equipment required to obtain service from a multiplicity of aids providing the same or similar functions. Space limitations, cost factors, and, in the case of aircraft, weight considerations obviate this. Nor can nations be expected to finance the provision of a variety of shore-based aids to serve mobile stations carrying such a multiplicity of equipments. It is evident, therefore, that ships and aircraft should, if possible, standardize on one type of aid in each distance category.

11. Another, but by no means secondary consideration, is the necessity for standardization of systems in the interest of avoidance of interference between radio services. For example, if one nation sets aside a certain band of frequencies for shipboard radar and this same band of frequencies is used for fixed service in another country, the ship might not be able to employ its radar near the second country without causing interference. World standardization obviates such difficulties.

Bands Proposed by United States for Marine Radio Aids to Navigation

12. These considerations were given due weight in the preparation of the following proposals for frequency service-allocations by the United States for the revision of Article 7 of the General Radio

Radio Regulations (Cairo Revision) 10 kc to 30,000 Mc at the International Telecommunications Conference.

Long-distance Navigation

10-14 kc for Navigational Service

13. Much thought has been given in several quarters of the world to the need for a standard, world-wide, long-distance navigational aid. As conceived, such aid could be available for use by both ships at sea and aircraft over the sea.

14. The band 10-14 kc is considered to be suitable for such purpose. It can carry large powers over great distances. For efficient propagation, however, its use is rather limited to land-based transmissions where antennas of the required height or length can be provided conveniently.

15. A number of systems have been developed to serve this purpose. One continuous wave system, now in the experimental stage, may prove worthy of standardization. Which system or systems will eventually occupy this band is still indeterminate. Nevertheless, the United States feels that this band should be set aside now for any ultimate continuous wave system which may later prove worthy of standardization.

Long-distance Navigation (Ships and Aircraft)

200-280 kc for Aeronautical Navigational Service
1800-2000 kc for Navigational (Loran) Service

16. Medium frequency LORAN is the only long-distance aid now in general use for long-distance service coverage for ships and aircraft. The LORAN chains were installed during the war and have been continued because of their long-recognized utility. As you are aware, LORAN is a pulsed emission navigational aid using the transmission of timed pulses from a "master" station at a specified characteristic rate and the re-transmission in synchronism of similar pulses from a second station, commonly termed a "slave". The difference in the time of arrival of pulses from the master and the slave determines a hyperbolic line of position. A position is fixed by the intersecting of a second line of position obtained from another pair of stations with the line obtained from the first pair.

17. The United States therefore is recommending to the Radio Administrative Conference that the medium frequency bands 1800-1900 and 1900-2000 kc be continued for LORAN in the MF spectrum and that

provision be made in the vicinity of 180 kc for service trials of LF LORAN so as to determine the extent of the improved coverage over land, as well as sea, of LORAN operating in this portion of the spectrum. The use of two or more bands of frequencies for LORAN does not aggravate the mobile receiver problem since a converter in the radio frequency portion of the receiver permits switching from one carrier frequency to another without duplicating the presentation portion of the receiver.

18. Besides LORAN, the United States has developed another aid, principally for air navigation, for the 200-280 kc band, namely, the LF Omnidirectional Range. The LF Omnidirectional Range is a narrow band continuous wave system providing, from a single site, radial track guidance throughout 360° of azimuth.

19. To offer to the International Telecommunications Conference as much flexibility as possible in deciding the allocation for the ultimate long-distance aid to be employed jointly by ships and aircraft, the United States proposes the band 200-280 kc as representing the over-all limits within which the final selection be made. It should be noted that the entire band 200-280 kc is not required for the ultimate long-distance aid to be selected. The remainder of the band 200-280 kc and the entire band 320-415 kc is required in the American Region for the continued use of a system of medium and short-distance aeronautical navigational aids which have been in operation for a number of years.

<u>Medium Distance Navigation</u>

<u>280-320 kc for Maritime Navigational (Beacons) Service</u>

20. The United States proposes the band 280-320 kc for the maritime navigational service employing the familiar radio beacon. In this band and its vicinity over 33 countries of the world provide over 600 radio beacons. These beacons serve ships of all countries provided with a direction finder capable of receiving beacon signals in and near this band. As you know, the Safety of Life at Sea Convention, to which many countries subscribe, requires that ships of certain specifications carry a radio direction finder. But apart from these, thousands of ships and smaller boats carry a radio direction finder on a voluntary basis in order to avail themselves of this valuable service.

21. The present allocation in the American Region is 285-315 kc. But because of continued and expanded use of this aid for many years to come for short and medium distance navigational purposes as

indicated, an increase in the width of this band to forty kc is considered by the United States to be a minimum, in spite of intense area and time sharing.

22. Economic and engineering reasons justify retention of this enlarged band for beacons. The position of this band in the spectrum has proved satisfactory. Heavy commitments by many countries in the radio beacon stations themselves and in the thousands of radio direction finder equipments carried aboard ship justify its continuation in this band. In fact the radio beacon facility is the simplest, most universally used short and medium range radio aid available today.

23. The United States believes the position in the spectrum of this band should not be changed, and that world standardization is necessary so as to preclude ships from having to tune to, and calibrate their direction-finding receivers for, different frequency bands in different parts of the world. The satisfactory service given by these beacons has made unnecessary the continued use of medium frequency shore-based direction finders.

<u>490-510 kc</u>

24. As we all know, 500 kc, with its guard band, is the international calling, distress, and emergency direction finding frequency recognized as meeting the pertinent requirement of the Safety of Life at Sea Convention (London, 1929). It is also incorporated in the General Radio Regulations (Cairo Revision).

25. Many other maritime mobile stations, such as those on board aircraft over the sea, voluntarily equipped vessels of all nations, and motor lifeboats are fitted to receive and transmit on this frequency. Without such a universal distress frequency, there would be no common frequency upon which any vessel could seek or give aid to any other vessel.

26. The adaptability of this frequency for the purpose and the world-wide commitments in equipment, procedures, and search and rescue systems, fully justifies its retention for its present purposes.

<u>Short-distance Navigation</u>

<u>152-162 Mc for Mobile Service, except Aeronautical</u>

27. The United States proposes that frequencies in the band 152-162 Mc be provided for short distance communications in the

Maritime Mobile Service other than with aircraft. Contemplated services are calling; safety and distress; general intership communications; ship-shore-ship operational communications; ship-shore common carrier public correspondence; and harbor traffic control communications. The frequency 156.81 Mc is recommended for universal standardization to be available for the exclusive use of the Maritime Mobile Service for short-range communication.

28. However, we are principally concerned here with navigational aspects of harbor traffic control communications. There appears to be an imminent requirement for the services of shore-based radar stations located near the approaches to, and in the vicinity of, harbors and ports for the location and direction of ships entering and leaving them. Since verbal instructions from the shore-based radar stations to the ships being directed will require communication facilities, it is proposed that such facilities be provided internationally on the frequency 156.81 Mc.

3000-3246 Mc
5460-5650 Mc
9320-9500 Mc

29. The United States proposes three bands for shipboard navigational aids in which pulsed navigational aids are permitted. These are the bands 3000 to 3246 Mc, 5460 to 5650 Mc, and 9320 to 9500 Mc with radar beacons centered on 3256, 5450, and 9310 Mc with a plus and minus guard band of 10 Mc.

30. The provision of three bands for shipboard maritime radar is the result of the successful use of pulsed radars during the war, and the success to date of the operational trials now being conducted by several countries to determine the over-all utility of radar for the maritime service. The particular significance of these bands must be adjudged by considering all three together. The band 3000-3246 Mc is known to be less susceptible to the effects of rain and snow which can cause obscuration or blurring of the presentation. Obscuration has been known to occur at 3000 Mc, but it is relatively less severe and occurs less frequently than at the higher frequencies.

31. The second major consideration is definition or the preciseness of the picture which the operator sees. In general, greater definition can be obtained at 9320-9500 Mc, but the evaluation of the over-all merits of the three bands must take into account the particular purpose which the navigator who uses the device primarily has in mind.

32. Reports from mariners who now are experimenting with radars indicate that in some waters the definition provided by a 3000 Mc radar is sufficient. On the other hand, proponents of 9000 Mc radar say that the ability of a ship to move safely in darkness or fog through a crowded harbor or in narrow straits is the criterion and that high definition of the order of that provided by 9000 Mc radar is essential.

33. In view of this, the United States believes that the only wise course is to provide three bands as mentioned, so that extensive operational trials in all kinds of weather and in all oceans may be conducted over an extended period of time. It is likely that a requirement will exist for all three bands for some time to come.

34. The band 5460-5650 Mc has been included in the United States proposals because it is believed that this band holds the most promise of striking an effective compromise between the advantages and disadvantages of the other two bands. While it is true that very little equipment and practically no operational experience is available to support the necessity of this 5000 Mc band, it is deemed highly important to provide it at this time, and for some years to come. If this is not done, it is unlikely that an allocation could in the future be made without disruption of other services which otherwise might become committed in this part of the spectrum, and where the cost of changes in the operational frequencies of equipment may be substantial.

35. The three radar beacon frequencies 3256, 5450, and 9310 Mc, with plus and minus 10 Mc guard bands complement the three shipboard radar bands. It is pointed out that these beacon frequencies are adjacent to, rather than within, the radar bands themselves. In general it is intended that shipboard radars may interrogate the radar beacons in the adjacent band. If they prove in practice to be essential to the mariner, and if it appears that ships generally will require two or three bands, the same number of radar beacons will be required.

36. It will be noted that I have made no mention of the so-called radio lighthouse. So far no requirement has been indicated in this country for that type of facility, but, nevertheless, we are anxious to learn of the progress of its development in other countries. It is our view that should this facility have to be provided for in the spectrum, it could be accommodated either in the band 2900-3000 Mc or in the band 3266-3300 Mc.

37. So much for the explanation of the specific United States frequency service-allocation proposals.

Summary and Conclusions

38. The United States is convinced that the frequency bands discussed here will accommodate efficiently and economically all the present and fore-seeable marine radio aids to navigation capable of meeting the needs of the modern navigator.

39. World agreement on systems and frequency spectrum requirements at this Meeting for introduction at the International Telecommunications Conference is our great opportunity.

40. Standardization of systems offers advantages to all nations. Standardization of systems reduces to a minimum a country's investment in land-based facilities. Standardization of systems likewise reduces to a minimum the radio equipment required to be carried aboard ship and aircraft. Otherwise ships would take on the aspect of floating radio laboratories and, through required extensive training, bridge crews would behave more like radio engineers than mariners.

41. But world agreement on standardization of systems is not enough. We must prepare ourselves to agree at the forthcoming International Telecommunications Conference on standardization of frequency service-allocations as well, if we are to have spectrum order and not disorder. Standardization of allocations reduces to a minimum the portion of the spectrum utilized throughout the world for a given service. Standardization of allocations permits orderly expansion of present systems. Standardization of allocations provides predetermined spectrum space for the introduction of new systems which may represent an improvement over those currently standardized. Standardization of allocations goes far toward mitigating the evil of interference. And standardization of allocations in this navigational service will encourage standardization in other services.

42. In conclusion, we are confident that the interests of our respective countries, whether direct or indirect, in international commerce will lead us all to international agreement on systems and on frequency bands for the benefit and vital promotion of world trade..... Thank you.

E. K. JETT
COMMISSIONER,
FEDERAL COMMUNICATIONS COMMISSION

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN · · · APRIL 28-MAY 9, 1947

THE SELECTION AND CONVERSION OF WAR DEVELOPED ELECTRONIC SYSTEMS FOR PEACETIME USE

- BY -

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REAR ADMIRAL, U. S. NAVY
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ABSTRACT

This paper presents general comments concerning aids to marine navigation and the suitability of various systems for peacetime use.

The importance of standardizing electronic aids to navigation is stressed, inviting particular attention to the consideration of frequency assignments at the coming World Telecommunications Conference.

Radio and electronic aids specifically mentioned are: Radar, Shoran, Loran, Medium Frequency Direction Finders, Radio and Radar beacons, and Very High Frequency Radio Communications.

Recommendations are also set forth as to requirements for navigational aids for position fixing in areas:

(a) Less than 3 miles from land
(b) Between 3 and 50 miles from land
(c) Over 50 miles from land

"THE SELECTION AND CONVERSION OF WAR DEVELOPED ELECTRONIC NAVIGATIONAL SYSTEMS FOR PEACETIME USE"

Introductory

1. Not long ago Electronics were playing an essential role in the conduct of the most extensive war the world has ever known. Aircraft were enabled to bomb pin-point targets through overcast and fog. Ships bombarded shore and ship targets without visual contact with those targets.

2. From March, 1944 to March, 1945 I had the privilege of commanding the new and fast U. S. Battleship Wisconsin. The Wisconsin operated as a part of the great Naval force in the Western Pacific under Admirals Nimitz, Spruance and Halsey. I can certainly state to you, Gentlemen, that I developed a deep affection for electronic navigational aids, particularly radar and Loran. They are marvelous aids to safe and effective navigation. One occasion I shall always remember was the typhoon we experienced in December of 1944 in which we lost some ships due to the intensity of the raging storm. There were several hundred Navy ships in the storm area. We were in formation. I recall that for a few hours we could not visually see even those ships nearest to us in the formation. But by radar we "saw" them readily and proceeded without fear of collision.

3. Today, electronic navigational aids, or applications of these equipments, are applied to peacetime pursuits. Ships are avoiding collision by the use of radar. With radar, ships are able to proceed at normal speeds in fog where not many years back it was necessary to stop or proceed slowly. Ships are maintained on their routes, saving time, money and fuel. Recently, an aircraft was lost in inclement weather some 150 miles north of Bermuda. The high powered U. S. air search radar, installed and operating on that island, located the aircraft and by means of radio communications directed it to the base for a successful landing. There are many examples of this nature with which you may be familiar.

4. A multiplicity of new radio and electronic devices and systems possessing potentialities for marine navigation have been developed. No doubt, most of these equipments would have been developed in time but the impetus of war hastened their development and adoption. Many of these wartime developments are adaptable to peacetime uses, including marine and air navigation, and will enhance the safety of life at sea and in the air.

5. The multiplicity of electronic navigational aids presents

many problems. One of these problems is the coordination and assignment of frequencies for equipments on a world-wide basis. The number of frequencies available for these devices is necessarily limited. Limitations on practicable weight, space, costs, complexity, and numbers of operating personnel make wide employment of certain systems unwise or impracticable at this time. We should avoid adoption of any world-wide plan which would require a ship, in going from one area to another, to change its equipment and techniques in order to obtain maximum benefits from those electronic navigational aids available in that second area. Furthermore, the consideration of the expense involved in using several different systems would make such a procedure impractical. Added weight in aircraft and the location of added units on board ship, constitute a problem which cannot be overlooked. Moreover, no man can be trained to operate every type of aid efficiently. The problem of employing an extensive technical crew would be a serious one. Hence, the need for world-wide coordination is apparent.

6. Let us consider some of these war-developed systems with particular regard as to how they can be effectively employed in peacetime.

7. Time does not allow me to fully explore all possible navigational aids or all possible combinations of aids. Therefore I shall make comments concerning only some principal aids, devoting particular attention to those whose use is common to aircraft and to ships. In the interests of economy, coordination and simplification, it is obvious that, we should make use of such aids as are common to both aircraft and ships, whenever and wherever practicable. Because of the scope of the subject, I shall confine myself to those prominent aids upon which the U.S. depends for marine navigation and which are practicable for use on a worldwide scale as soon as agreements can be reached.

RADAR

8. As you know, Radar had its technical beginning many years ago, but its development proceeded slowly, gaining momentum in the late 1930's, and reached its present improved state due to the urgencies of war. Radar augments to a remarkable degree our sense of sight, not only as regards distance, but also in its capacity to penetrate darkness or fog. With Radar installed in ships and aircraft we are able to "see" our objective whether it be a buoy, island or harbor entrance. During darkness or inclement weather we are enabled to "see" other ships in time to avert danger of collision. The availability of reflectors and beacons installed on shore has added greatly to the capabilities of Radar for marine navigation close to land.

9. The U. S. Coast Guard is taking an active part in the coordination of U. S. Commercial Marine Radar equipment. There is a program in progress for the improvement of U. S. Air and Marine Navigational Radar beacons and their installation on an extensive basis for use in marine navigation and all-weather flying operations of military and civil aircraft. In addition, there is an extensive program in progress under the coordination of the U. S. Navy and the Coast Guard to further improve channel and buoy detection by Radar. The use of precision Radar, reflectors and beacons in off-shore hydrographic surveys is being set up by several organizations in the U. S. It is anticipated that there will be considerable resultant information that will be of use to marine navigation in general.

10. Ground Controlled Approach Radar (GCA) now used for landing aircraft in low visibility, is an application of a war-time development to peacetime needs. Ground Controlled Approach Radar equipment is probably well known to many of those present. The usefulness of this system was well demonstrated this past winter at Mitchel Field, Long Island, and Patuxent, Maryland, when several civil aircraft including one transoceanic were successfully landed under weather conditions in which the planes might otherwise have crashed. Ground Controlled Approach Radar is assuming increasing importance in civil, as well as military operations. It is probable that similar techniques and a similar system can be applied to harbor control and marine navigation.

11. The U. S. Weather Bureau, the Military Services and the CAA are using Radar for the detection and tracking of storms with excellent results. Ships and aircraft are also using Radar for the location of storms in their vicinity and as an aid in avoiding dangerous storm areas.

SHORAN

12. Shoran is a precision range triangulation system, employing two beacons which re-radiate pulse on two different frequencies after initial "interrogations" are made from the transmitter in the craft. This system was designed primarily as a precision blind bombing device at relatively short ranges (100-200 miles), but can also be used to navigate to a specific point. Because of its accuracy this equipment is being used extensively by agencies concerned with aerial mapping, hydrographic work and geologic survery.

LORAN

13. Loran is a well-established long-range navigation system

employing 2 or 3 transmitting stations to cover a given area. It functions on the principle of precise time measurements of pulse transmission from two or more synchronized transmitters. It is a position-fixing system giving lines of position. Its current accuracy is better than 1% of the distance from the ship to the transmitting station in the service area.

14. Operational trials were conducted in 1942 and operational expansion commenced in 1943 and has been continued on a wide scale. Loran chains have been established which in general extend from Japan down through the Ryuku Islands, the Philippines, Marianas and Marshall Islands, Hawaii, Aleutians, Alaska, the West and East Coast of the U.S.; thence by way of the North Atlantic to Europe. Thus, a considerable portion of the shipping lanes of the world are already covered by Loran transmitters available for instant use by any ship or aircraft equipped with a suitable receiver.

15. The existing Loran system now provides unique and valuable service. Its present capabilities are as follows:

(a) Daytime range 600 to 800 nautical miles
Nighttime range 1,400 nautical miles

(b) The service area of one chain of 3 stations is about 1,000,000 square miles over water, and about 150 transmitting stations of the present design would be sufficient to provide service over all the important sea routes and over-water airways of the world.

16. The apparatus now generally used was built under the designs developed when the system was new and this apparatus is more complex than necessary. Possibilities are bright for improvements in Loran which is already an excellent and reliable system. Laboratory work and field tests, now well advanced, show that the present characteristics can be greatly improved. The day-time range can probably be increased to as much as 1,500 miles under severe noise conditions, and to as much as 3,000 miles under light noise conditions. Accuracy can be increased to within 1 or 2 miles at 1,000 miles from stations. Receivers are in production which are direct-reading, that is, no skill will be required to take readings. The service area of each new Loran system chain is about 5,000,000 squre miles, and only 60 or 70 stations will be required to give good coverage over all important land and water airways of the world.

17. Briefly, the salient characteristics of the Loran system, viewed from the postwar application angle, are as follows:

(a) Range 1,000 to 1500 miles by Standard Loran and to 3000 miles by Low Frequency Loran (dependent upon noise conditions).

(b) Stability, reliability, and accuracy-very high.
(c) Receivers will be available at moderate cost.
(d) Aircraft receiver weight - now 35 pounds.
(e) Position fixes can be obtained under all weather conditions.

18. A practical application now available for use by ships and aircraft equipped with Loran is that of piloting or "homing" to a harbor. Using it, the aircraft or ship is able to reach harbor channels with minimum delay, and with certainty, even when position fixes by other methods have been impossible for long periods while approaching the coast. Each spot on the coast, each harbor, each buoy, each airfield, has some Loran line of position running through it. The particular line passing through any desired destination is determined from the Loran chart. The ship or aircraft approaching the coast merely navigates, well off shore, so as to reach that particular line of position, as read on the Loran receiver. Having reached that line, the Loran receiver is allowed to remain on the setting for that line; and the ship is steered so that the Loran receiver continuously corresponds to that setting. If the ship veers right or left from its course, the indicator will show the change immediately. The ship is maintained on a course which is the charted Loran line of position and necessarily arrives at the desired destination.

19. Under war-time conditions, in the U.S. Navy sixteen weeks is the time usually allowed to train a man in the necessary mathematics, astronomy and geography to become a possible celestial navigator. This statement includes the assumption that the student has the necessary groundwork beforehand. As a result of this training, the man is able to obtain a celestial fix in from 20 to 40 minutes, using a sextant. This same man can be trained to operate existing Standard Loran in three days or less! Also instead of the laborious celestial navigation method, how simple it is to use Loran which results in an accurate long range fix in three minutes or less!

20. During the war over 3,000 ships and 30,000 aircraft were equipped with U. S. Standard Loran receivers. The military services using Standard Loran included:

U. S. Navy
U. S. Army Air Force
British Royal Navy
British Royal Air Force
Royal Canadian Navy
Royal Canadian Air Force

U. S. Naval Transport Service
U. S. Air Transport Command

By means of Loran, a Trans-Atlantic ship convoy made a perfect landfall following a 3 day's storm in which no celestial observations were obtained. 4 years ago a commander of a naval ship unit operating in the Aleutians stated that Loran was used regularly and results were most successful. This commander also reported that he considered the Loran installation the outstanding single piece of equipment yet installed. An Allied bomber, hit by anti-aircraft fire which destroyed radar, compass, and all other navigational instruments except Loran, was able to reach its base by homing on a Loran line of position.

21. Loran has the outstanding advantage of having been tried and found effective for both marine and air navigation. It has received recognition by the International Civil Air Organization. Constant research over a period of several years has improved Loran to the point where I firmly believe it to be the best available answer to marine and air long range navigational problems. Certain Loran chains are established and considerable Loran equipment is already available for installation in ships and aircraft.

22. In addtion to Standard Loran a Low Frequency Loran has been extensively tested in the 180 kc band. On the basis of these tests the Technical Division of the Provisional International Civil Aviation Organization at Montreal reported that Low Frequency Loran is the system which at present offers the greatest promise of meeting functional requirements as a long distance aid to air navigation. Low Frequency Loran, particularly from the Marine standpoint, is still in the experimental stage. Continued tests lead to hope, however, that certain technical problems which have so far prevented its standardization, can be overcome in a reasonable time.

MEDIUM FREQUENCY DIRECTION FINDERS

23. Pending the establishment of a more satisfactory world-wide system which will be available to all ships and which all ships will be able to employ, it is believed that mariners should continue to make use of shipboard MF/DF with radio beacons and that the system should be improved wherever practicable. This, of course, is not a war-developed aid, but it is a system with which we have long been familiar and which has been in use for many years. I believe that use of this system should be continued as a means for establishing position fixes by those ships not equipped with Loran and Radar, and may be employed as a secondary means of posi-

tion fixing for some time to come. The United States has abandoned the use of shore-based radio direction finder stations for purely marine navigational purposes. However, I believe it would be of interest to you to know that there are in active service, a few shore-based direction finders, both medium frequency and high frequency, situated at various locations within the United States. These stations are available for Search and Rescue purposes only. I would like to emphasize that these facilities as well as many radio and radar beacons are giving satisfactory operational results for marine and air navigation and are available for emergency use.

VERY HIGH FREQUENCY VOICE RADIO COMMUNICATIONS

25. Very High Frequency Radio Communications was exploited during the war and has now reached a very satisfactory stage of development. VHF found many uses during the war and now, although it is not, strictly speaking, a navigational aid, it can be used in marine navigation as an aid in harbor control and for offshore communications.

GENERAL

26. There are other electronic navigational aids under consideration and test by various U.S. Agencies, for adaptation to Marine Navigation. As mentioned before, I have discussed in this presentation only certain equipments which seem to me most suitable and practicable for use on a world-wide scale as soon as agreements can be reached.

27. I think that you will agree that the matter of frequency assignment at the coming World Telecommunications Conference will put emphasis on the necessity for early standardization of electronic navigational aids. Use of systems common to marine and air navigation is desirable for many reasons, among which are:

(1) Reduction of the number of transmitting installations required.

(2) Reduction of expense and number of personnel required.

(3) Simplification of such training as is required by operators.

(4) Reduction of demands for frequency allocation.

(5) Adoption of world-wide systems which are capable of serving all potential users.

28. Speaking from an operational viewpoint I believe that Radar has become an almost indispensable aid for preventing collision at sea. It is valuable also for position fixing when within "line-of-sight" range of land, including maneuvering in harbors. In order to permit accuracy of 50 yards and to allow instantaneous position and track fixing when within "line-of-sight" range to land, those U. S. equipments considered satisfactory include shipboard high resolution Radar operating in the 3000, 5000 and 9000 mcs bands, assisted by active and passive radar aids. In addition, radio beacons with shipboard medium frequency direction finders, as well as VHF radio communications used as a secondary aid, are highly desirable for use under such conditions. If we increase the distance of the ship from land to an intermediate range, say from 3 to 50 miles, the equipment which I have just mentioned will also satisfy the operational requirements. At such a range, an accuracy of 200 yards to one-half mile should be required and from 1/2 minute to 5 minutes should be permitted for position and track fixing. In cases wherein a ship is over 50 miles from land an accuracy of 1% should be allowed and 15 minutes is sufficient to allow for obtaining a fix. U. S. equipments whose performance is well within these limits, are: Standard Loran operating in the 1800-2000 kcs band and radio beacons with shipboard medium frequency direction finders.

29. I should like to emphasize that it is my sincere hope that this conference will not only demonstrate to you the suitability of some war developed equipment for world-wide adoption but will lead also to effective standardization of world-wide marine navigational aids and ease the problems of frequency assignments. I am convinced that while time and engineering will improve those systems already in use there will be a minimum of obsolescence of older equipments as improvements are made. The basic principles of the U.S. systems now in use are sound and satisfactory for world-wide use. I believe it would take a long time to obtain definite proof as to the usefulness of any speculative or theoretical system which has not been in wide use for a considerable period of time to allow its full evaluation to be accomplished. I believe that we should remain open-minded to new ideas but at the same time accept those ideas, systems and devices which have been tested and used operationally over a long period and have been proven effective and satisfactory in performance.

30. The detailed and technical aspects of the systems and equipments I have mentioned will be more fully covered by later speakers. There are U. S. representatives present who are qualified and ready to answer such technical questions as you may care to ask at this time, and who will be pleased to show you

later what the U. S. now has to demonstrate.

Earl E. Stone
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Chief of Naval Communications

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN · · · APRIL 28-MAY 9, 1947

THE USERS VIEWPOINT ON RADIO NAVIGATIONAL SYSTEMS FOR OCEAN GOING VESSELS

- By -

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ABSTRACT

As the title suggests, this paper attempts to present in an over-all manner the viewpoint of the commercial shipowner with respect to the various electronic navigational devices that have been made available, or potentially available, to him in recent years. It attempts to point out the factors which he must take into consideration with respect to these new devices. And of most importance, it explains the dilemma that the shipowner will continue to be confronted with until such time as definite international agreements are arrived at which will enable him to make use of these new devices throughout the world.

THE USERS VIEWPOINT ON RADIO NAVIGATIONAL SYSTEMS FOR OCEAN GOING VESSELS

1. I am speaking at this meeting as a representative of the National Federation of American Shipping, which represents a majority of the high seas shipowners of the United States. We appreciate this opportunity to present our views with respect to Radio Navigational Systems for Ocean Going Vessels, and hope that our opinions as users and potential users may be helpful to your deliberations.

2. According to the best information available at the present time, the active United States ocean going shipping fleet, as operated by the U. S. Maritime Commission and private interests, consists of 2728 vessels. Of these vessels there are 2042 dry cargo type, 591 tankers and 95 passenger vessels. The operating range of these vessels will vary from those plying the coastal trades and which perhaps never get more than 30 miles or so from shore to those assigned on distant runs all over the world. The operations of these vessels are controlled by companies of varying sizes. One company may have its sole investment in one or two ships; others may have fleets of vessels as large as fifty or more.

3. In most cases, the men who own these ships are not themselves engineers. At the same time you will find them, without exception, to be experts in the economics of transportation and the numerous problems of the sea. And because the electronic developments of recent years are not yet in general usage, the average shipowner is unfamiliar with them. His approach to these new devices, therefore, although sympathetic, will be one of questioning from an operational point of view.

4. On the other hand, those of us in this gathering are supposed to know the answers to questions concerning the new electronic developments. That is, in fact, the reason for this meeting - to discuss problems coincident with them. But to the shipowner, the man who in the last analysis must be the one to determine what equipments he is going to purchase and install aboard his vessel or vessels, the terms Radar, Loran, Consol,

Gee, Popi, Decca, et cetera, do not mean anything. For the most part he doesn't know what these devices are, nor what they can do. And he wants to be sure, when he buys one of them, that he is getting something that will "pay off" in one way or another. He wants to be sure that each equipment placed aboard his ship has a maximum of usefulness.

5. No one will take issue with the fact that the main purpose of commercial shipping is to transport persons and goods from one point to another as economically and safely as possible. Aside from its social implications, safety enters into the problem primarily for the reason that, if things went wrong habitually, ocean transportation would cease to be economical. No one will blame the shipowner, then, for wanting to be assured of the economic usefulness of these new devices - whose names mean nothing to him - before he can be expected to commit himself concerning them.

6. I think then - regardless of whether he would express his feelings in these same words or not - that the average shipowner would establish as a basic requirement for electronic aids to navigation systems for ocean going vessels, the requirement that the device or system will

a) enable the ship to do something it couldn't do before; or

b) enable the ship to do better, something which it did before in another way; or

c) that it increase safety.

Further, that it must obtain any or all of the above within an economically justifiable cost.

* * * *

7. In reviewing the reports of our first meeting in London last Spring I have been struck by the fact that, of the half dozen or so new electronic devices which came up for discussion, shipboard radar is the only device which is self sufficient. The entire equipment and all phases of its operation are contained aboard ship. Basically, it does not depend upon the utilization of shore devices although beacons and reflectors can be introduced as a valuable adjunct.

8. I think this fact is important because in a large measure it serves to explain why the shipowner is comparatively more enthusiastic about its use than any of the other devices. It also serves to explain why, even in its present state, installations can be made and operational usage developed independent of definite agreements, international or otherwise, concerning a standard device to meet all operational needs. The point I am trying to make is, that of all these new devices, shipboard radar is peculiarly adapted to individual acceptance or rejection without the introduction of outside considerations. True, there must be some agreement concerning beacon frequencies and associated shore devices before the ultimate in shipboard radar can be obtained upon a world-wide basis, but in the sense that it can function independently of such devices it is already an acceptable world-wide marine aid to navigation.

9. When I say that shipboard radar is already an acceptable world-wide marine aid to navigation I do not mean to imply that we have accepted any particular type, or standard of specifications. Because of the nature of things these will have to be determined over a period of time. We are sure, however, that the final determination of the operational usage of radar has not yet been fully reached.

10. You will hear later on in the meeting of the detailed analysis and thorough experimentation on this very subject which has been carried out by the operators of commercial shipping in our Great Lakes region. I am sure that you will be impressed, just as we have been, by the completeness of the operational research program in connection with the requirements of the type of vessel and navigational problems peculiar to those waters. For our part, we have had to handle the problem of examining the radar requirements of high seas

shipping in a different way. We are concerned with numerous types and classes of vessels operated for various purposes and traveling under different conditions throughout the world. This diversity of purpose and condition may well lead to the development of radar requirements not now considered. Nevertheless, the requirement for adequate anti-collision protection will not change. Faced with the daily safety of thousands of lives and millions of dollars worth of cargo we have had but little alternative as an industry but to put on our radars where they will do the most good as a safety aid. This is being done voluntarily, and with the realization that what we have today may not be what we will want tomorrow. This, I might add, is the only method by which we can hope to obtain the operational information which at some future date can be presented as representing over-all requirements; or, as determined, the specific requirements for specific purposes.

11. It might be of some interest to this meeting to know that as of the present time there are over one hundred commercial shipboard installations aboard U. S. vessels; and that if our statistics mean anything, new installations are going aboard at the rate of 20 or 30 a month. At the same time, steps are being taken by the National Federation of American Shipping, to accumulate information concerning the operation of these installations. Among other things it is hoped that - based upon the cumulative experience of shipowners now using radar - answers to the following questions can be obtained for the benefit of the ocean going shipping industry as a whole:

a) Why is it being installed;

b) what uses is it being put to;

c) how is it working out, and

d) the economic benefits to be derived from its usage.

12. Although we would like to have had something more concrete to present in this respect, it must be recognized that it will take some time to accumulate sufficient operational information to arrive at specific conclusions. This information, although interesting, is not necessarily vital to the success of the present

meeting. The immediate questions with respect to radar which appear to be of most importance to this meeting are:

a) Whether there is a necessity for the allocation of more than one frequency band for the operation of shipboard radar, and

b) whether provision should be made for the operation of associated shore devices.

13. A great deal has been said concerning the relative merits of different frequency bands for radar operation. Specific information on this subject will no doubt be furnished during the course of these meetings. The point of view of ocean going shipping is that, for an interim period until the operational aspects of shipboard radar can be thoroughly tried out under all conditions, provision should be made for the international allocation of three separate frequency bands for this purpose in the regions of three-centimeters, five-centimeters and ten-centimeters. We feel that equipments should be manufactured to operate on each of these bands in order that a thorough examination of their respective merits can be obtained over a period of years under the wide variety of usages occurring in high seas shipping operations.

14. I will not go into any detail concerning the associated shore devices of radar. Suffice it to say that, although the safety or anti-collision element of shipboard radar is recognized, the complete exploration of operational uses can not be made without examination of the associated shore devices. For this reason we feel that for any period during which provision is made for the operation of shipboard radar equipments in several frequency bands, similar provision should also be made for the operation of associated shore devices. It is our opinion that it is only through a complementary system of shore devices that the maximum utilization of radar for navigational purposes can be expected.

* * * *

15. This brings us to a consideration of medium range navigational aids. Except perhaps for certain specialized types of vessel operation, the requirements for medium range navigational aids would appear to be met by a combination of shipboard radar and shipboard radio direction-finding; and under some conditions these two devices tend to replace each other for this purpose.

16. Because radar is still in the process of growing up, it would be both difficult and foolish to attempt to predict at this stage whether it can or will ever completely replace radio direction-finding as a medium range aid to navigation. For one thing, shipboard radio direction-finding equipments are themselves subject to improvement both as to accuracy and speed of interpretation. For another, they are useful at greater range. A final item in their favor is the ability to track. This has its safety implications in those cases where one ship in distress must depend upon another for rescue.

17. On the other hand it may be found that by the use of appropriate shore devices, radar charts, and other facilities, the utility of radar can be extended to meet all coastwise navigation and landfall requirements. If this should be found true, its complete replacement of direction-finders as a navigational aid could then be seriously considered, at least for coastwise shipping. This would leave the safety or mutual assistance factor to be met, possibly by a strong shore-based search and rescue organization, utilizing direction-finding networks and search aircraft.

18. It is recognized that among other newly developed electronic devices there are some that are considered medium range aids to navigation. It is also recognized that they are capable of doing an excellent job. But from the shipowners point of view, do they really fulfill a need? Shipboard direction-finding equipments have been in use for many years. Procedures and frequencies have been standardized. Shipboard direction-finding is, in effect, the only marine radio aid to navigation system in general usage throughout the world at the present time. Ninety percent of all of our sea going vessels are equipped with radio direction-finders. And they have installed them voluntarily. I will predict that over a period of years they will

accept shipboard radar with the same enthusiasm. Our navigating personnel are thoroughly experienced in the use of direction-finding equipments, and are rapidly becoming versed in the operation of shipboard radar. Any additional equipments for medium range purposes would seem to be unnecessary, particularly as the two in use already tend to overlap each other in certain functions.

19. Now the point to be considered here - and it is one entirely of economics - is that the shipowner would get no additional return sufficient to justify the installation of any of the other new electronic devices as a medium range aid alone. Or to put it another way, they just don't meet our basic requirement. The only conclusion that can be drawn from this is that, until the full capabilities of radar for navigational purposes can be explored, the average shipowner will continue to look upon shipboard direction-finding as his primary medium range aid to navigation system.

* * * *

20. In a broad sense, with the exception of radar, all of the new electronic devices under discussion at this and our previous meeting attempt to perform a common navigational function. This is particularly true of the medium and long range aids. They differ from each other with respect to the equipments and methods used for the performance of that function. However, they all have one thing in common. Each one of these devices, at least in its present form, depends upon a specific type of shore installation and a specific type of ship installation. Now it is an inescapable fact that when the usefulness of a shipboard equipment is dependent upon shore installations over which the shipowner has no control, he is going to be very cautious about investing in one until the need for service is amply demonstrated.

21. I feel sure that the need for service is much less with respect to long range aids to navigation than with respect to medium range aids. The further a vessel is from shore, the less need exists for frequently fixing a position. Likewise, the speed in fixing a

position is of less importance. I also feel sure that the need for service with respect to long range aids is of less importance to surface shipping than to aviation. Nevertheless there is a need for service. With respect to the U. S. System - LORAN - a number of shipboard installations have been in regional use for months aboard privately owned and operated vessels. A much greater number are in use, or are being installed, aboard government owned vessels operated by our commercial shipping companies. Our deck officers receive training in its operation. The shipowners, as users, would like to see the uncertain situation regarding long range aids clarified, and would welcome the establishment of any system for joint use with aviation. But they have noted the failure on the part of aviation - even with an international organization of their own - to come to any clear cut and final decisions for a world-wide long range navigational system. Therefore, it is only reasonable to expect that although the advantages of long range aids are recognized, the shipowners, as a group, will refrain from wholehearted acceptance of any long range navigational system until they can be assured both as to its permanence over a period of years, and the ability to use it over a wide area.

22. It is recognized that standardization with respect to long range aids to navigation presents a most difficult hurdle. Standardization requires the closest kind of international coordination and agreement, and in many ways involves matters of national policy and economics which go beyond technical considerations. However, from the marine point of view it does not appear that the primary consideration in the selection of long range aids can or should be left entirely in our hands. Let me explain that this way. It is hard to conceive of the selection of any long range system for aircraft which would not be usable by ships. And for economic reasons there should be no duplication of long range aids as between the two services of aviation and marine.

23. Now I do not intend to infer that we, at a marine meeting of this sort, should sit back and say to our aviation people and to the International Civil Aviation Organization, "The problem is entirely yours". Not by any means. There are certain things we can do, and should do. From the users point of view I would suggest the following specific items as considerations:

a) The needs of surface shipping for a long range aid to navigation are not sufficient to justify the establishment of facilities for this purpose, on a world-wide basis, for use by the marine services alone.

b) The establishment of long range aids to navigation for use by surface shipping can be justified only if predicated upon a joint use by other services.

c) It is essential that marine usage be considered as a factor in the selection of any long range air aid to navigation. Failure to do this would have the effect of removing the advantages of long range navigational service from the possibilities now open to shipping.

24. Whether these considerations are acceptable as final conclusions or not is beside the point. The important thing, it seems to me, is that we should arrive at some conclusions with respect to long range aids at this meeting; and to pass them on to the governments and aviation interests as representing our opinions.

25. Now here we have the crux of the matter I think. We mortals have attempted to rival with our electronic devices the power of the moon and the stars and the sun as position fixing aids. And I think that insofar as producing workable equipments are concerned we have succeeded. But in one respect we have failed - at least up to the present time - and that failure has been in connection with our inability to effect world-wide standardization of the most suitable of these new developments.

26. With this in mind I place a challenge before the meeting. Collectively we have been brilliant enough to develop these electronic tools of service - let us collectively be clever enough to resolve the difficulties that now bar the way to their universal usefulness.

EDWARD C. PHILLIPS
ACTING DIRECTOR OF TELECOMMUNICATIONS
NATIONAL FEDERATION OF AMERICAN SHIPPING

THE USERS VIEWPOINT ON RADIO NAVIGATIONAL SYSTEMS FOR OCEAN GOING VESSELS

Summary of Conclusions

1. Basic Requirement

The average shipowner would establish as a basic requirement for electronic aids to navigation systems for ocean going vessels, the requirement that the device or system will

a) enable the ship to do something it couldn't do before; or

b) enable the ship to do better, something which it did before in another way; or

c) that it increase safety.

Further, that it must obtain any or all of the above within an economically justifiable cost.

2. Radar

For an interim period until the operational aspects of shipboard radar can be thoroughly tried out under all conditions, provision should be made for the international allocation of three separate frequency bands for this purpose in the regions of three-centimeters, five-centimeters and ten-centimeters.

For any period during which provision is made for the operation of shipboard radar equipments in several frequency bands, similar provision should also be made for the operation of associated shore devices. It is only through a complementary system of shore devices that the maximum utilization of radar for navigational purposes can be expected.

3. Medium Range Aids to Navigation

Until the full capabilities of radar for navigational purposes can be explored, the average shipowner will continue to look upon shipboard direction-finding as his primary medium range aid to navigation system.

4. Long Range Aids to Navigation

Although the advantages of long range aids are recognized, the shipowners, as a group, will refrain from wholehearted acceptance of any long range navigational system until they can be assured both as to its permanence over a period of years, and the ability to use it over a wide area.

Specific considerations:

(a) The needs of surface shipping for a long range aid to navigation are not sufficient to justify the establishment of facilities for this purpose, on a world-wide basis, for use by the marine services alone.

(b) The establishment of long range aids to navigation for use by surface shipping can be justified only if predicated upon a joint use by other services.

(c) It is essential that marine usage be considered as a factor in the selection of any long range air aid to navigation. Failure to do this would have the effect of removing the advantages of long range navigational service from the possibilities now open to shipping.

5. Challenge

Collectively we have been brilliant enough to develop these electronic tools of service - let us collectively be clever enough to resolve the difficulties that now bar the way to their universal usefulness.

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN. · · · APRIL 28-MAY 9, 1947

THE APPLICATION OF MARINE RADAR TO LAKE, RIVER AND PASSAGE NAVIGATION

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ABSTRACT

This paper describes briefly the Great Lakes Radar Operational Research Project carried out during 1946 under the auspices of Lake Carriers' Association. Lake, river and passage navigation is found to require radar which will serve three functions, namely, (1) collision prevention, (2) position finding in open waters, and (3) navigation combined with collision prevention in confined waters. The requirements for all purpose navigational radar capable of serving all three functions are set forth as they were developed for the Great Lakes with comment regarding the similarity of these requirements for open water, river, passage and harbor navigation elsewhere.

(This paper is based upon the complete report on "Great Lakes Radar Operational Research Project" copies of which are available to those attending this conference. Since the slides and illustrations used are some of those appearing in the large, more comprehensive report, the same figure numbers have been used. Not all figures are included in this paper nor do they always appear consecutively.)

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THE APPLICATION OF MARINE RADAR TO LAKE, RIVER AND PASSAGE NAVIGATION

1. At the International Meeting on Radio Aids to Marine Navigation held in London in May, 1946, it was my privilege to describe the Great Lakes Radar Operational Research Project, work on which at that time was just being inaugurated. Today, almost one year later, I am pleased to be able to present to this conference the results which have been obtained.

The Great Lakes Radar Operational Research Project

2. The operational research studies I will describe were carried on under the auspices of Lake Carriers' Association, an organization representing 318 large bulk cargo freighters of United States registry operating on the Great Lakes. Shortly following the close of navigation in 1945, the Association secured the cooperation of six of the principal United States radar manufacturers in a project designed to develop by field study the requirements for all purpose navigational radar for the Great Lakes and similar waters. These companies were: General Electric Company, Radiomarine Corporation of America, Raytheon Company, Sperry Gyroscope Company, Inc., Western Electric Company, Incorporated and Westinghouse Electric Corporation. Six steamship companies, members of Lake Carriers' Association, were paired with the six radar manufacturers. Each of the steamship companies selected one of its largest vessels for the studies and on this vessel in each instance was installed a radar set designed and developed by the radar manufacturer working with it.

3. The results obtained by the season's testing of the six radar units were studied individually by the navigating personnel of the radar equipped vessels, by engineers of the manufacturers, and collectively by representatives of the steamship companies and by Jansky & Bailey, consulting radio engineers for Lake Carriers' Association. Copies of the complete report describing the project and setting forth the conclusions reached are available to those attending this conference. Included in the report are specifications for Great Lakes all purpose navigational radar.

4. The Great Lakes which lie between the United States and Canada are five in number. Fig. 1 shows a chart of the Great Lakes. The total area of the lakes and their connecting waters is 95,160 square miles (246,655 km^2). Navigation is possible for comparatively large vessels throughout the lakes and as far east as Ogdensburg, New York, and Prescott, Ontario, on the St. Lawrence River. Further details with respect to the character of the lakes and connecting waters, the length of season of navigation, the types of shipping, the kinds of cargo carried, and the density of traffic, are contained

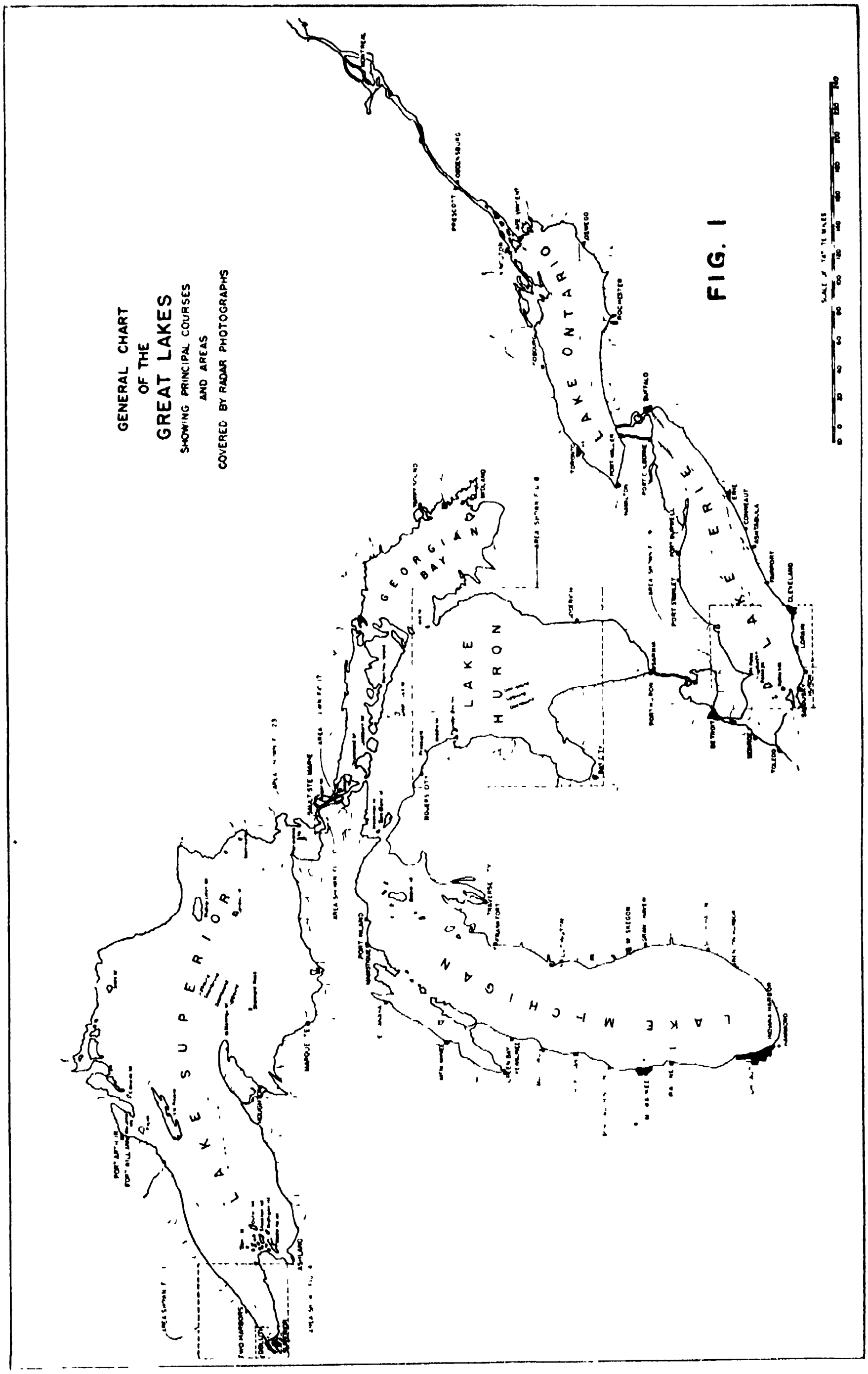
GENERAL CHART
OF THE
GREAT LAKES
SHOWING PRINCIPAL COURSES
AND AREAS
COVERED BY RADAR PHOTOGRAPHS
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
GEORGIAN BAY
LAKE ERIE
LAKE ONTARIO
BUFFALO
CLEVELAND
TOLEDO
DETROIT
ROCHESTER
OSWEGO
TORONTO
HAMILTON
ASHLAND
DULUTH
SUPERIOR
TWO HARBORS

FIG. I

in the complete report already mentioned.

5. As the studies progressed, it soon became evident that a ship-borne radar set is a multi-use device. More specifically, it became clear that as an instrument of navigation radar is capable of performing three separate and somewhat distinct functions.

a. The prevention of collision in open waters under conditions of poor visibility.

b. Accurate position finding in open waters under all conditions of visibility.

c. Navigation and the prevention of collision in rivers, harbors and passages under conditions of poor visibility.

6. Next, it became desirable to define for the Great Lakes the areas and regions throughout which each of these three functions would be performed. Fig. 8 is a second chart of the Great Lakes designed to permit an analysis of the functions radar can serve in navigating these waters. This chart shows (1) the areas in the open lakes more than 15 miles (24 km) from shore, (2) the areas in the open lakes less than 15 miles (24 km) from shore, and (3) the rivers, passages and connecting waters.

7. An adequate all purpose radar can be used for anticollision purposes in the open lakes throughout both the areas beyond 15 miles (24 km) and those within this distance of shore. Such a radar can also be used for accurate position finding at all times within 15 miles (24 km) of shore and during a fairly large percentage of the time at distances considerably beyond this limit. The third function, namely, navigation in confined waters, is confined to rivers, harbors and passages.

8. Since an all purpose radar is a multi-function device, more specifically a three function device, it is possible to analyze the requirements for each function and to set them down separately. The requirements may then be consolidated so as to specify a device which will serve all three functions.

9. The use of radar for the prevention of collision, position finding and navigation in confined waters can best be described by the aid of photographs of the Plan Position Indicator, that is the PPI, presentations obtained aboard Great Lakes vessels.

The Anticollision Function

10. In open waters a well designed radar will identify the loca-

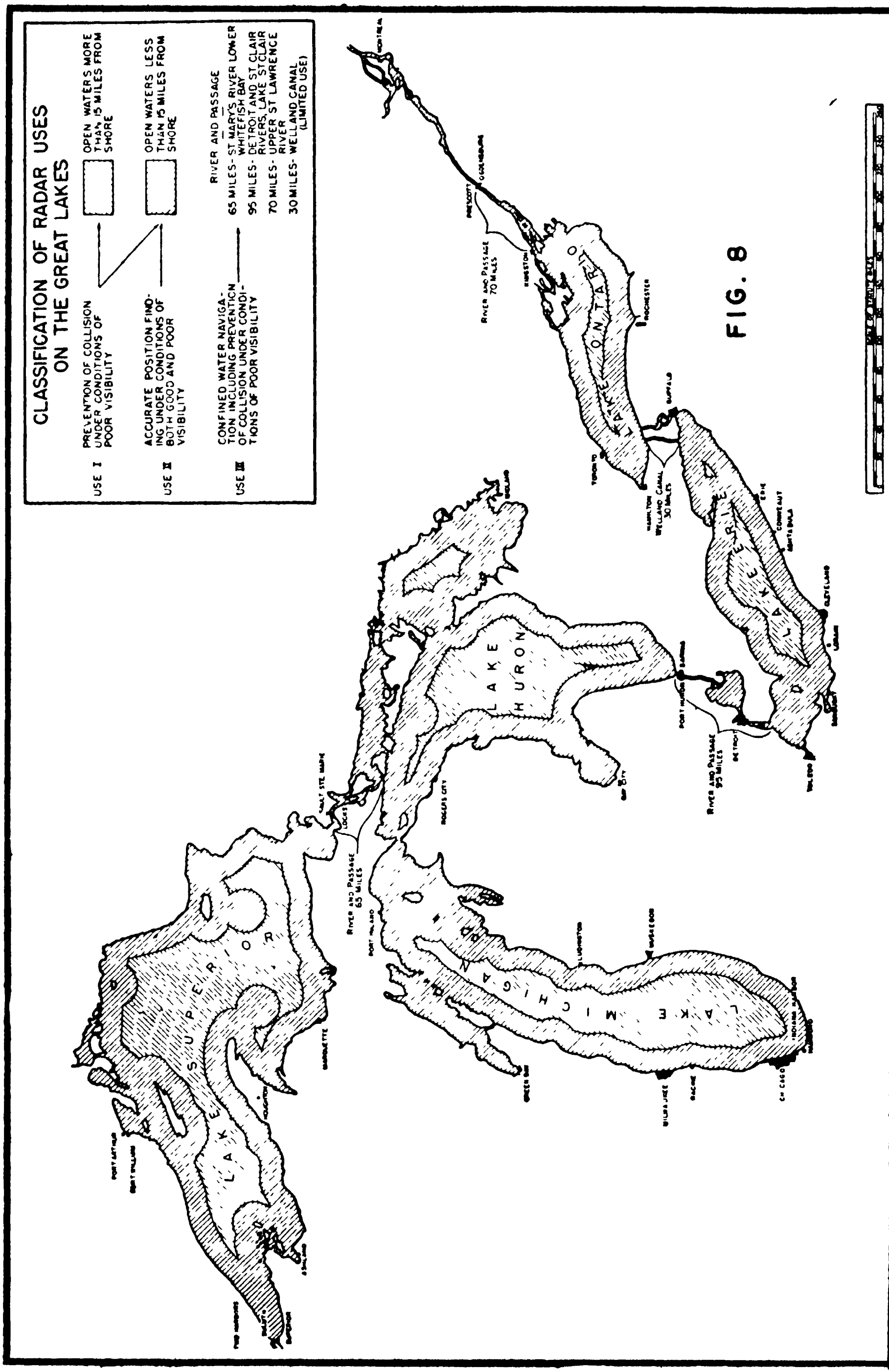
CLASSIFICATION OF RADAR USES
ON THE GREAT LAKES
USE I
PREVENTION OF COLLISION UNDER CONDITIONS OF POOR VISIBILITY
OPEN WATERS MORE THAN 15 MILES FROM SHORE
USE II
ACCURATE POSITION FINDING UNDER CONDITIONS OF BOTH GOOD AND POOR VISIBILITY
OPEN WATERS LESS THAN 15 MILES FROM SHORE
USE III
CONFINED WATER NAVIGATION INCLUDING PREVENTION OF COLLISION UNDER CONDITIONS OF POOR VISIBILITY
RIVER AND PASSAGE
65 MILES - ST MARY'S RIVER LOWER WHITEFISH BAY
95 MILES - DETROIT AND ST CLAIR RIVERS, LAKE ST CLAIR
70 MILES - UPPER ST LAWRENCE RIVER
30 MILES - WELLAND CANAL (LIMITED USE)
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
RIVER AND PASSAGE 65 MILES
RIVER AND PASSAGE 95 MILES
RIVER AND PASSAGE 70 MILES
WELLAND CANAL 30 MILES
DETROIT
PRESCOTT
KINGSTON
ROCHESTER
BUFFALO
TORONTO
CLEVELAND
TOLEDO
ERIE
ROGERS CITY
BAY CITY
PORT HURON
MARQUETTE
HOUGHTON
PORT ARTHUR
CHICAGO
MUSKEGON
GREEN BAY
RACINE
MILWAUKEE

FIG. 8

tion of nearby vessels and permit a determination of the courses they are travelling in sufficient time to prevent collision. The reflections on the PPI which indicate the presence of large vessels are quite pronounced and easily identified. The detection of the presence of smaller vessels is not so easy but nevertheless even this is not too difficult.

11. Fig. 9 is a chart of the west central portion of Lake Erie. Fig. 10 is a PPI photograph taken aboard a vessel located as shown on Fig. 9. The direction of the ship's head is the direction of the bright line shown on Fig. 10 drawn from the center to the left to zero on the azimuth scale. The concentric circles on this photograph are fixed range rings and the distance between them represents 5 miles (8 km). Therefore, the total range shown on the PPI is approximately 35 miles (56 km).

12. The bright spots appearing on the photograph indicate the presence of other vessels. Directing attention to the area within the third circle, that is, the area within 15 miles (24 km) of the vessel, it can be seen that there are 9 bright spots indicating the presence of 9 vessels. Two of these, distant approximately 7.5 miles (12 km) and 40° on the starboard bow, are quite close together. To prevent collision, attention should first be directed to the movement of the reflections indicating the presence of nearby vessels. With bad visibility conditions, the maximum range shown on the PPI would be changed to 15 miles (24 km) in which case the area within the third range circle would occupy the entire PPI. With the movement of these ships under constant observations appropriate steps could readily be taken to prevent collision.

The Position Finding Function

13. When within approximately 15 miles (24 km) of shore in the open lakes a well designed radar on the proper frequency is admirably adapted to the accurate determination of position practically 100 per cent of the time. It can also be used for this purpose a very large percentage of the time at distances considerably beyond 15 miles (24 km) when propagation conditions are favorable. Position finding by radar is made possible by the fact that shore configurations, islands and large fixed objects give pronounced reflections providing they lie within range. In Fig. 10 there are shown reflections from large portions of both the northern and southern shore line of Lake Erie. There is also present a pronounced reflection from Pelee Island 25 miles (40 km) ahead. Comparison of the configurations of the shore reflections on Fig. 10 with the chart, Fig. 9, makes possible the identification of points, islands, bays, etc. These having been identified their distance and bearing may be measured by the use of appropriate ancillary devices. The line previously referred to extending from the center of the PPI to the left is called the heading

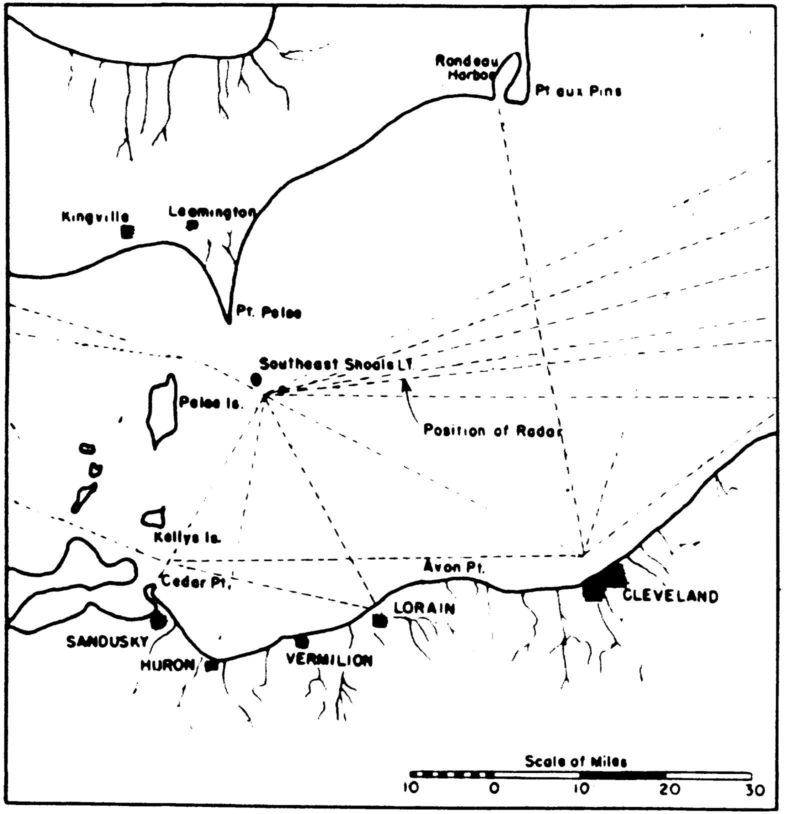

FIG. 9
PORTION OF CHART OF LAKE ERIE

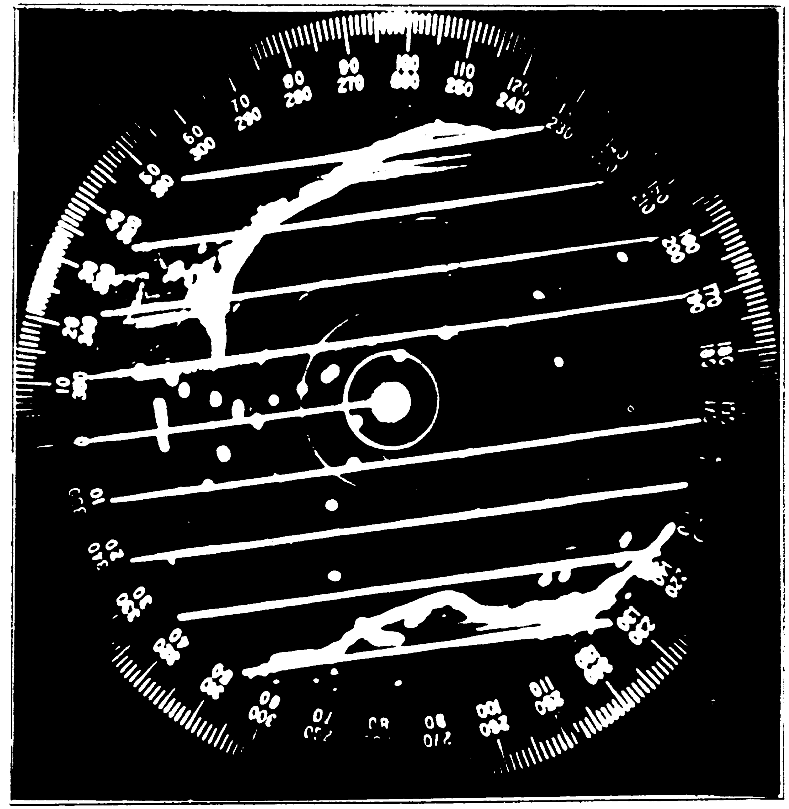

FIG. 10
RADAR PHOTOGRAPH LAKE ERIE RANGE
30 MILES. DISTANCE BETWEEN RANGE RINGS
5 MILES.

marker and is produced by electronic means. The parallel lines and azimuth scales shown on Fig. 10 are drawn on transparent material mounted directly over the PPI. This assembly may be rotated by hand. One of these lines coincides exactly with the position of the heading marker and this is called a bearing cursor. At the top of Fig. 10 there is a marker, fixed in position, called the lubber line indicator. This can be seen at 99^{o} on the outer azimuth scale which corresponds to 261^{o} on the inner azimuth scale.

14. At the time the photograph, Fig. 10, was taken the electronic PPI circuits were interlocked with the gyrocompass control. Under these conditions of operation the reflections from shore are always correlated with the chart. That is to say, the direction of the lubber line indicator is always north, the direction of the ship's head being indicated by the direction of the electronic heading marker. This type of presentation is called "true" and is most useful in position finding.

15. If the interlocking control with the gyrocompass is absent or disconnected, the top of the picture, that is the direction of the lubber line indicator, is always the direction of the ship's head. This is called a "relative" presentation. It is preferred by many navigating officers in rivers and narrow passages.

16. In Fig. 10, with the bearing cursor superimposed on the heading marker, the direction of the ship's head may be read from the lubber line indicator. This direction is 261^{o}. The distance to Point Pelee on the Canadian shore may be determined by counting the fixed range rings. Its distance is 20 miles (32 km). If the bearing cursor were rotated so that it passed directly over the tip of Point Pelee then the relative bearing of this point could be determined by reading the angle between the bearing cursor and the electronic heading marker. This would be found to be 21^{o}. The "true" bearing of Point Pelee could be found with the bearing cursor in this position by a direct reading on the inner azimuth scale against the lubber line marker. This would be found to be 282^{o}.

17. The parallel lines appearing upon Fig. 10 are not standard. They are useful in certain navigational situations. To illustrate, the first parallel line to the north of the heading marker on Fig. 10 is removed 7 miles (11.3 km). Since this line passes just across the end of Point Pelee it is evident that if the vessel maintains its present heading without drift it will be 7 miles (11.3 km) off Point Pelee when abreast.

18. Fig. 10 illustrates the two basic requirements for accurate position finding which are (1) reflections from a sufficiently large portion of the shore line to permit the identification of shore configurations, and (2) the ability to make accurate measurements of

bearing and distance.

19. The outstanding advantage possessed by radar as a position finding instrument is the comparative ease with which bearing and distance can be determined simultaneously as contrasted with other methods now in use. When the "bow and beam" method of fixing position is used the speed of the vessel must be known and time interval between 45 and 90 degree relative bearings to a fixed point must be determined. Position finding with a ship-borne radio direction finder necessitates the taking of cross bearings upon two or more fixed radio stations and the plotting of these bearings upon a chart. In contrast, with a radar set properly designed and equipped for the accurate taking of bearings and the measurement of distance, position may be determined instantly. Frequently, propagation conditions will be such that the position finding function may be performed out to the maximum range of the radar provided there is shown on the PPI a sufficiently extensive portion of the shore line to permit the identification of shore configurations.

20. For position finding it is important to be able to select the range scale for the PPI best adapted to the navigating situation at hand. The two charts and four radar photographs shown in Figs. 11 to 16 inclusive illustrate the use of radar for position finding in approaching Duluth Harbor at the western end of Lake Superior. Range scales of 20, 10, 5 and 2 miles (32, 16, 8 and 3.2 km) were used. In each case the range selected was the one best adapted to yield the most accurate information on the vessel's position. When Fig. 12 was taken the ship was 17 miles (27.4 km) from Duluth Harbor. When Fig. 16 was taken the ship was 0.6 miles (0.97 km) from the entrance. From here in, the vessel faced the problems of confined water navigation where the 2 and 1 mile (3.2 and 1.6 km) range scales prove most useful.

Radar Navigation in Rivers, Passages and Harbors

21. The safe progress of a vessel proceeding through rivers and narrow passages is dependent upon the location of objects in its immediate vicinity. These may be lighthouses, beacons, buoys, points of land, etc., or they may be other vessels either anchored or under way. Therefore, there is no basic difference between the use of radar for prevention of collision and for position finding in confined waters. Fundamentally, what is required under poor visibility conditions is the prevention of collision at close range with objects some of which are stationary and some movable coupled with identification of those objects by their relative position.

22. Fig. 17 is a portion of the chart for the northbound channel in the St. Marys River west of Neebish Island. Fig. 18 is a radar photograph of the same area when the radar equipped vessel was loca-

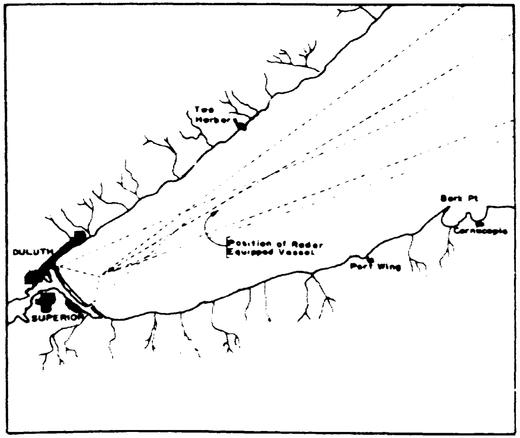

FIG 11
PORTION OF CHART FOR WESTERN END OF LAKE SUPERIOR

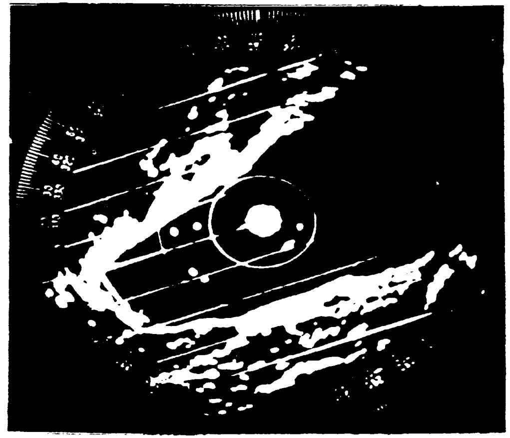

FIG. 12
RADAR PHOTOGRAPH, WESTERN END OF LAKE SUPERIOR. RANGE 20 MILES DISTANCE. BETWEEN RANGE RINGS 5 MILES

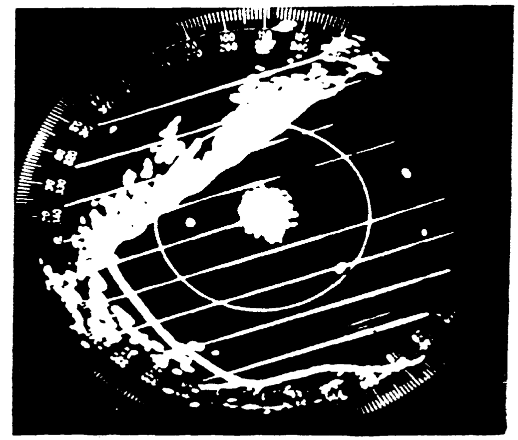

FIG. 13
RADAR PHOTOGRAPH WESTERN END OF LAKE SUPERIOR RANGE 10 MILES DISTANCE. BETWEEN RANGE RINGS 5 MILES

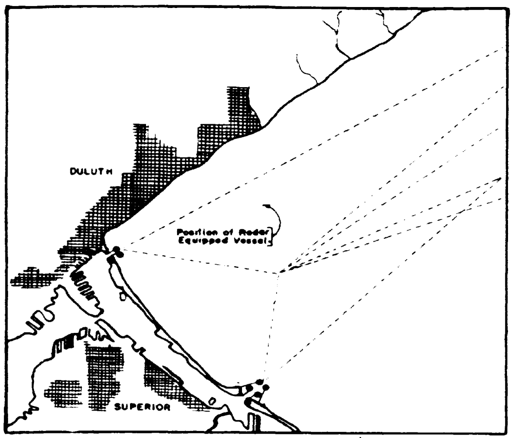

FIG 14
SMALL PORTION OF CHART FOR WEST-END OF LAKE SUPERIOR

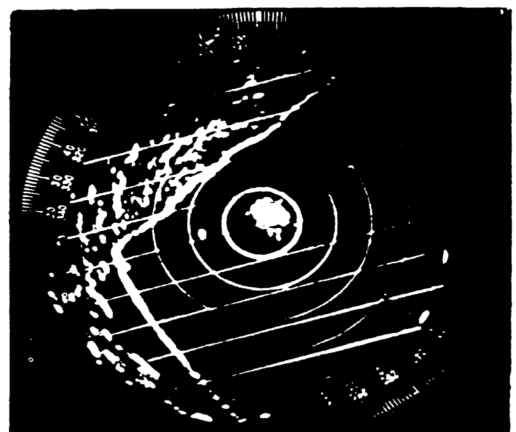

FIG 15
RADAR PHOTOGRAPH WESTERN END OF LAKE SUPERIOR. RANGE 5 MILES DISTANCE. BETWEEN RANGE RINGS 1 MILE

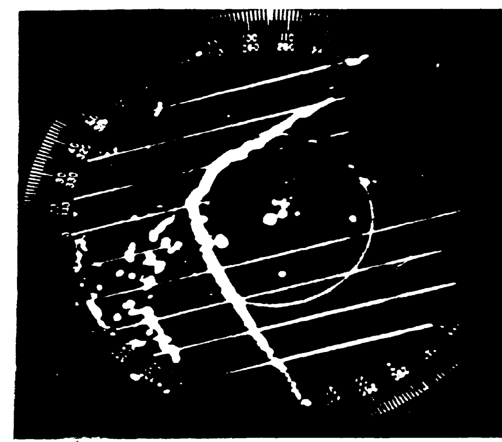

FIG. 16
RADAR PHOTOGRAPH WESTERN END OF LAKE SUPERIOR. RANGE 2 MILES DISTANCE. BETWEEN RANGE RINGS 1 MILE

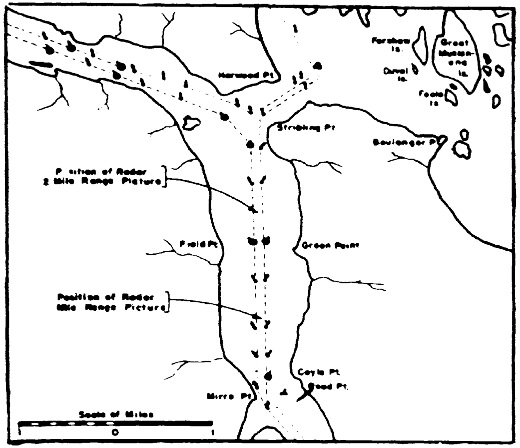

FIG 17
CHART OF PORTION OF UP BOUND CHANNEL ST. MARY'S RIVER.

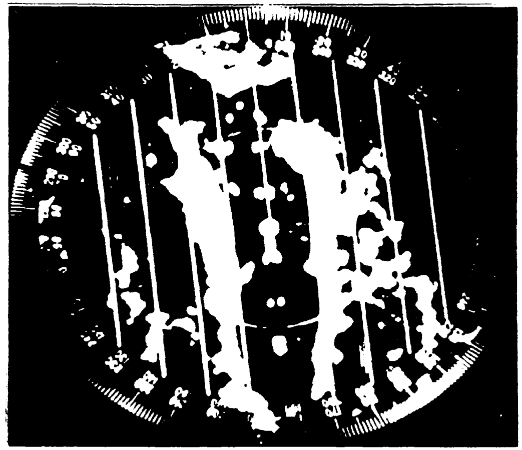

FIG. 18
RADAR PHOTOGRAPH PORTION OF ST MARY'S RIVER. 2 MILE RANGE, 1 MILE BETWEEN RANGE RINGS.

FIG. 19
RADAR PHOTOGRAPH PORTION OF ST. MARY'S RIVER. 1 MILE RANGE.

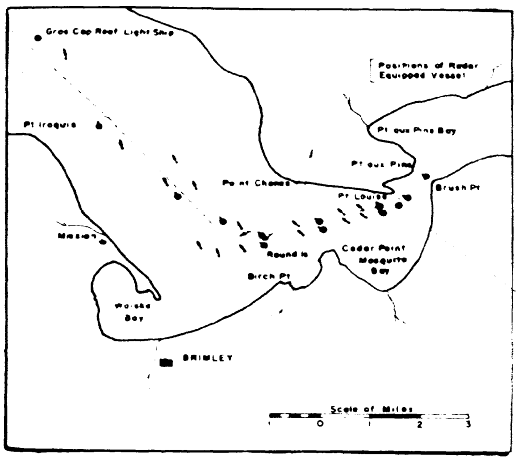

FIG. 20
CHART OF A PORTION OF WHITEFISH BAY IN LAKE SUPERIOR

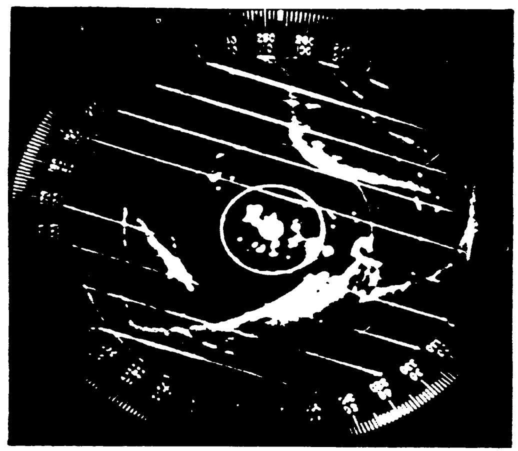

FIG 21
RADAR PHOTOGRAPH WHITEFISH BAY BEFORE TURNING TO ENTER BUOYED CHANNEL. 4 MILE RANGE, 1 MILE BETWEEN RANGE RINGS

FIG. 22
RADAR PHOTOGRAPH WHITEFISH BAY AFTER TURNING TO ENTER BUOYED CHANNEL. 4 MILE RANGE, 1 MILE BETWEEN RANGE RINGS.

ted as shown by the upper arrow on Fig. 17. Here the range scale is 2 miles (3.2 km). The land configuration around Stribling Point is clearly recognizable. There is a vessel following astern, distant 1.2 miles (1.9 km). The 2 mile (3.2 km) range scale permits a quick survey of buoys and traffic in the vicinity of and above Stribling Point where a turn must be made to the left. However, precise control of the vessel would be easier with the range scale adjusted for a maximum range of 1 mile (1.6 km) as shown on Fig. 19. (This photograph was taken a few minutes before Fig. 18, the vessel being at the position shown by the lower arrow on Fig. 17.) In Fig. 19 the intensity of the electronic heading marker has been reduced to permit a better showing of the two pairs of buoys ahead. Note the reflections from the aft end of the 605 foot (185 m) ship carrying the radar. The vessel astern is just to the left of a buoy and distant 0.9 mile (1.45 km).

23. Figs. 20, 21 and 22 illustrate the value of a range scale of the order of 4 miles (6.4 km) in waters somewhat less confined than those portrayed in Figs. 18 and 19. Fig. 20 is a portion of a chart of Whitefish Bay at the eastern end of Lake Superior. Figs. 21 and 22 are radar photographs taken aboard a vessel downbound in Whitefish Bay. Fig. 21 was obtained just before the vessel turned to the left to enter a channel 1000 feet (305 m) wide. Fig. 22 was obtained just after the turn had been completed. It can be seen that the heading marker and the bearing cursor lie between the pairs of buoys ahead. The photograph shows that there were no large vessels in the channel ahead for a distance of at least 2.5 miles (4 km). The next step in navigating this channel under conditions of poor visibility would be to first reduce the range to 2 miles (3.2 km) and later to 1 mile (1.6 km) as the more confined waters are entered.

24. The terminus of the channel the vessel was entering is the locks at Sault Ste. Marie. Fig. 23 shows a portion of the chart for this area. Fig. 24 shows a PPI photograph of the same area taken with the 1 mile (1.6 km) range scale in use. The vessel was approximately three-fourths of a mile (1.2 km) from the pier which divides the entrance to the two groups of locks.

Use of Radar to Show Density of Traffic

25. During the course of the radar studies on the Great Lakes there was a PPI photograph taken on Lake Huron at a time when propagation conditions were such as to show reflections from shore and from ships at distances out to 65 miles (105 km). Figs. 4 and 5 show this photograph and a chart which was prepared from it to show the density of traffic along the courses travelled on Lake Huron. The positions of 44 vessels are shown on the chart and in the photograph.

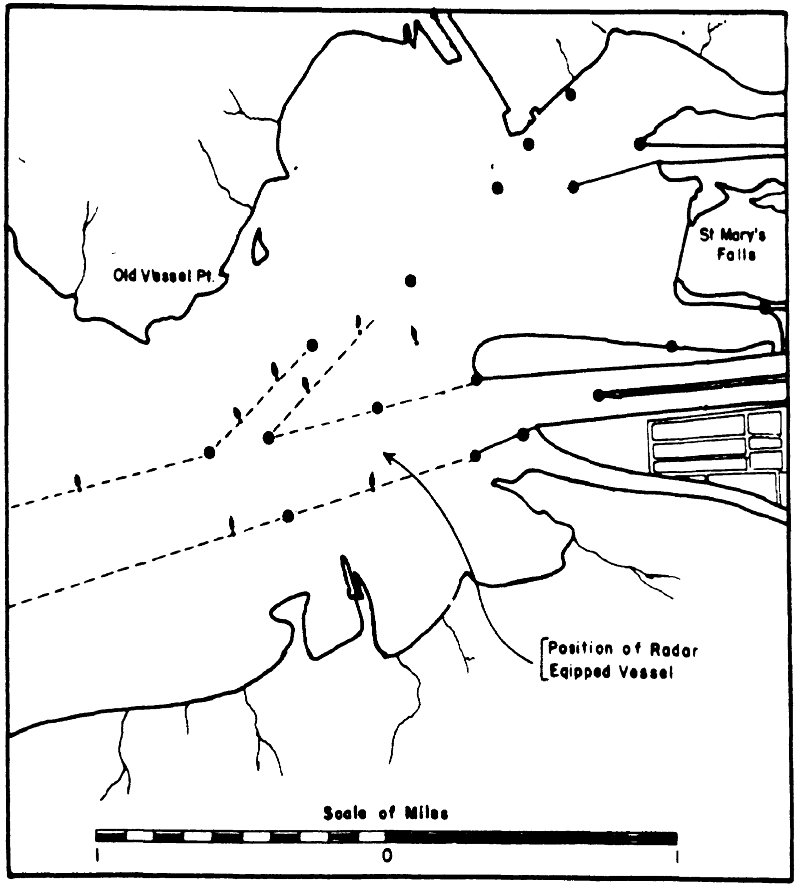

FIG. 23
PORTION OF CHART SHOWING APPROACHES TO THE AMERICAN LOCKS AT SAULT STE. MARIE, DOWNBOUND.

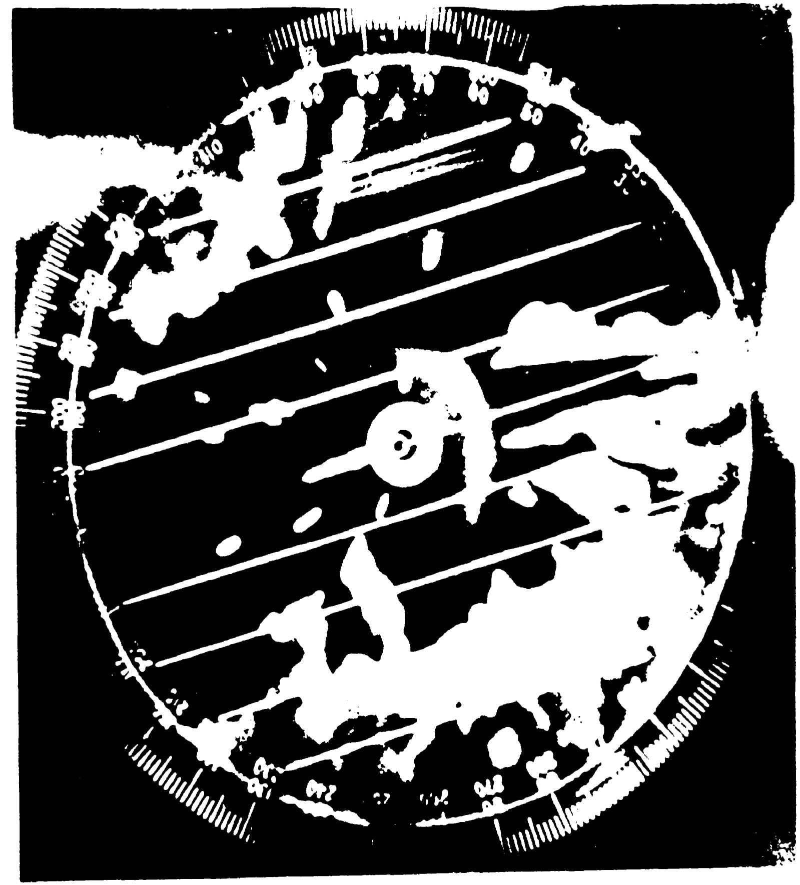

FIG. 24
RADAR PHOTOGRAPH SHOWING APPROACHES TO THE AMERICAN LOCKS AT SAULT STE. MARIE, RANGE 1 MILE.

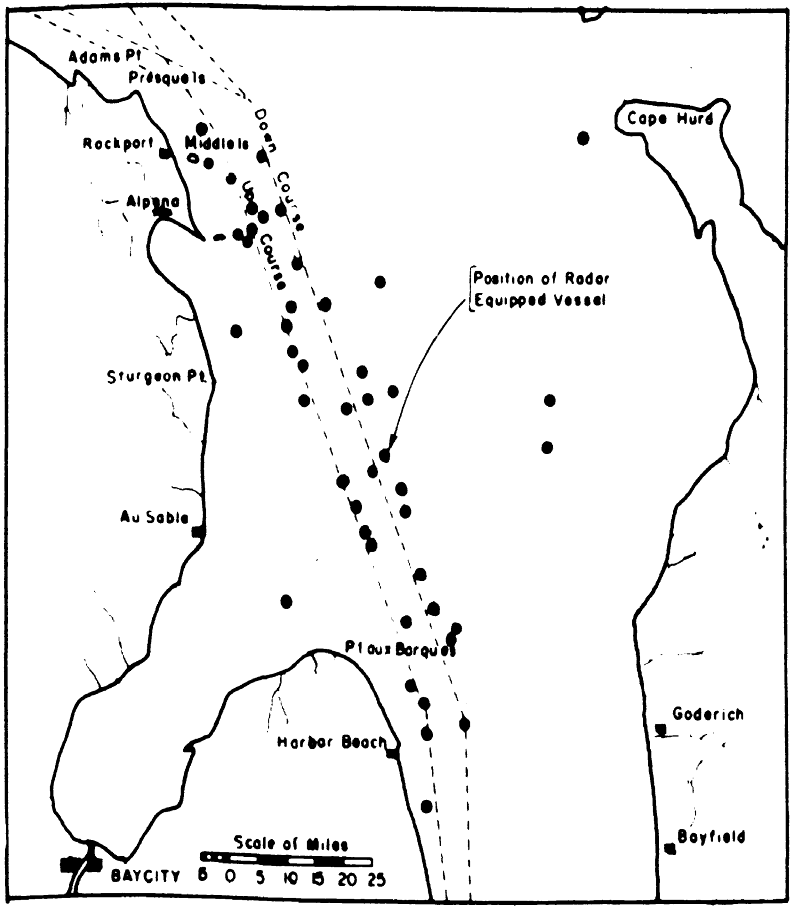

FIG 6

CHART PREPARED FROM RADAR PHOTOGRAPH SHOWING DENSITY OF TRAFFIC ON LAKE HURON.

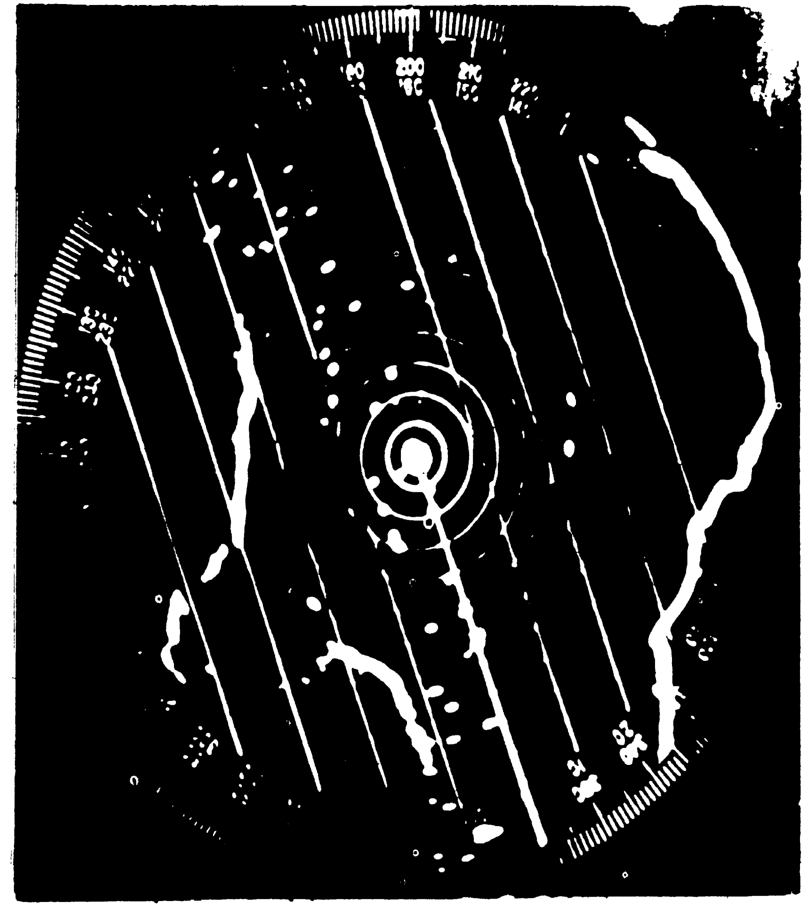

FIG 7

RADAR PHOTOGRAPH USED TO PREPARE CHART SHOWING DENSITY OF TRAFFIC ON LAKE HURON

Factors Affecting the Capabilities of Marine Radar

26. An important factor affecting the maximum range of a radar is its peak pulse power. Its ability to detect the presence of objects at close range is determined by the width of the transmitted pulse and certain other characteristics of the electronic circuits. The degree to which the PPI presentation is geometrically correct and free of distortion is dependent upon the "sweep linearity". Satisfactory sweep linearity also contributes to the accurate measurement of distance.

27. The degree of resolution possessed by a radar is determined partly by the width of the transmitted pulse which affects range resolution and partly by the horizontal width of the radiated beam which affects bearing resolution. (Resolution may be defined as the ability to portray two objects close together, as for instance, two ships, by separate reflections on the PPI. The closer the objects for a given distance from the radar without their reflections merging into a single spot, the higher the degree of resolution.)

28. The horizontal width of beam radiated from an antenna, or received by it, is dependent upon the physical dimensions and design of the antenna. The size of an antenna necessary to produce a sufficiently narrow beam for a high degree of resolution is a function of frequency. The higher the frequency the smaller the physical dimensions can be for a given width of beam. Therefore, as a practical matter the choice of a radio frequency for radar operation is a matter of great importance in determining the degree of resolution which can be obtained.

Requirements for Collision Prevention

29. The minimum requirements which a radar must possess if its use is to be limited to the prevention of collision in the open waters are comparatively few and not difficult to meet. A maximum range of 15 miles (24 km) will be sufficient except on a ship having a speed of 30 miles (48 km) per hour or greater where warning of the presence of a ship 15 miles (24 km) distant would not be sufficient. For ranges as limited as this, high power will be unnecessary. Excluding use for position finding and for confined waters navigation, a high degree of sweep linearity and the ability to show reflections from objects as close as 300 feet (91.5 m), will be required. Since for collision prevention in open waters high resolution is not needed, either the 10,000, 5,000 or 3,000 megacycle bands will be satisfactory. A radar limited in design to the minimum requirements for collision prevention should be used only for this purpose. Attempts to perform other functions with it might produce unfortunate results.

Requirements for Accurate Position Finding

30. A radar properly designed for accurate position finding will not only serve this function but it will also do a better anticollision job than one which barely meets the minimum requirements listed above. The attributes which are important for accurate position finding are as follows:

a. Sufficiently high power and range capability to reproduce enough of the shore line on the PPI to permit the identification of land configurations. (To identify the location of points on land distant 15 or 20 miles (24 or 32 km) it is desirable to have a range capability of 40 miles (64 km).)

b. Proper range scales so that the correct range adjustment may be made for the situation at hand. (After a point on shore has been identified by correlating as much of the shore line display with the chart as can be seen by using a long range, a shorter range adjustment should be selected for the measurement of bearing and distance. A very satisfactory series of range scales for position finding is 4, 8, 20 and 40 miles (6.4, 12.8, 32 and 64 km).)

c. A high degree of sweep linearity and high accuracy in the calibration of the fixed range rings.

d. Accurate and easily manipulated azimuth rings and bearing cursor with proper illumination.

e. Circuits for the "true" form of PPI presentation and a control for shifting instantly from "true" to "relative" and vice versa.

f. The availability of a variable range indicator calibrated in appropriate units.

g. High bearing and range resolution with particular emphasis on the former to permit the taking of accurate bearing and distance readings.

These requirements are severe but easily within the capabilities of the art today. It does not appear that they can be met by radar units with antennas of reasonable size operating on the 3,000 megacycle band. It is doubtful if they can be met on any frequency below the 10,000 megacycle band. If position finding radar is to serve its full usefulness it must produce substantially as accurate results as other methods for determining fixes.

Requirements for Radar Navigation in Rivers, Passages and Harbors

31. For confined waters radar navigation both high bearing and range resolution are imperative. It is not difficult for a well designed 10,000 megacycle band radar installation to pick up standard lighted buoys at six miles (9.6 km), standard unlighted metal buoys at 4 miles (6.4 km) and to differentiate between such buoys 300 feet (91.5 m) apart at a distance of 1 mile (1.6 km). While a minimum range down to 300 feet (91.5 m) is satisfactory, a still lower minimum range would be valuable in some situations.

32. If the use of radar is to be limited to confined waters, as for instance, inland rivers, then the longer ranges and the higher power necessary to produce reflections on the PPI at these ranges are unnecessary. A very satisfactory series of range scales is 1, 2, 4 and 8 miles (1.6, 3.2, 6.4, and 12.8 km). (Note the overlap in function as the 4, 8, 20 and 40 mile (3.2, 6.4, 32 and 64 km) ranges have already been defined as most useful for position finding.

Consolidated Requirements for an All Purpose Radar

33. If the requirements for both accurate position finding and river and passage navigation are satisfied, a completely adequate radar for the prevention of collision will result. Such a radar will have adequate power to give a range of 40 miles (64 km) under favorable propagation conditions, a high degree of range accuracy at the medium and long ranges, high resolution, a minimum range limit of 300 feet (91.5 m) and a sufficient number of range scales so that the proper one may be selected without too great a change in the proportions of the PPI picture in shifting from one range position to another. The unit will be equipped with a variable range indicator, well designed azimuth scales and bearing cursor and adequate controls to enable the adjustment of the circuits to secure maximum efficiency under all conditions of use.

The Importance of Apparently Minor Mechanical Features

34. An important function of operational research is to direct the attention of the designing engineer to seemingly unimportant mechanical characteristics of apparatus which under test proved to affect seriously the efficiency of use. The 1946 Great Lakes Radar Operational Research Project furnished many illustrations.

35. Undue parallax between the bearing cursor and the face of the PPI tends to destroy accuracy of bearing measurement. Even so simple a fault as unsatisfactory azimuth dial illumination may completely vitiate the use of radar for position finding. The effectiveness of control knobs and switches is vitally affected by their

accessibility, shape, grouping and ease of operation. In fact, the entire usefulness of the device in the hands of those who must operate it is dependent upon the care and attention given these purely mechanical details. Operational research directs attention to minor mechanical flaws, thereby enabling the manufacturer to correct them before embarking upon quantity production.

Application of the Results Obtained from the Great Lakes Radar Operational Research Project to the General Marine Navigational Problem

36. The operational studies described in this report were undertaken to develop the requirements for radar for Great Lakes navigation only. It is recognized that climatic conditions, character of seas and other factors on the Great Lakes may be quite different from those encountered at certain other parts of the world. Therefore, the relative emphasis on the functions performed by radar may be different elsewhere. This should be considered in applying the conclusions given here to other waters.

37. Analysis of a typical 891 mile (1,434 km) trip from Conneaut, Ohio, on Lake Erie to Duluth, Minnesota, on Lake Superior, a much travelled course on the Great Lakes, shows that (a) 30 per cent of the time the vessel will be in the open lakes more than 15 miles (24 km) from shore, and (b) 50 per cent of the time it will be in the open lakes but within 15 miles (24 km) of shore, and (c) 20 per cent of the time it will be in rivers, channels, and confined waters. This means that on such a trip a properly designed and built radar will be available (1) 80 per cent of the time for the prevention of collision under conditions of poor visibility, (2) at least 50 per cent of the time for accurate position finding regardless of conditions of visibility, and (3) 20 per cent of the time for navigation and the prevention of collision in confined waters. The reason these percentages add up to more than 100 per cent is, of course, that when a vessel is in the open waters but within 15 miles (24 km) of shore radar can perform simultaneously as a position finding and an anticollision device. A study of the courses travelled by the Great Lakes vessels will show other percentages of the same order of magnitude. An analysis of the courses travelled by coastwise vessels and by vessels navigating courses such as those between the United States and Alaska will show somewhat similar percentages with probably less emphasis on navigation at distances more than 15 miles (24 km) from shore.

38. The most general type of itinerary is, of course, one including all three classes of waters, namely, (1) open waters more than 15 miles (24 km) from shore, (2) open waters less than 15 miles (24 km) from shore, and (3) confined waters. If a ship's itinerary is limited to two classes of waters, then these will be (2) waters

less than 15 miles (24 km) from shore and (3) confined waters. This suggests that an all purpose radar, intended for the most universal use, should provide adequately for position finding and for navigation in confined waters. In so doing it will automatically provide anticollision protection.

Conclusions

39. The following general conclusions have been reached as a result of the Great Lakes Radar Operational Research Project:

a. Radar is destined to become not only an important safety device but a major instrument of navigation for lake, river and passage navigation.

b. Since a marine radar is an instrument of navigation, its operation and use must be placed directly in the hands of those responsible for the control of the ship, that is, the ship's navigating officers.

c. In addition to its great value as a safety device a properly designed radar, capable of performing efficiently all three of the functions described in this report, will greatly expedite the movement of vessels upon which it is installed. It is not unreasonable to expect that the value of time saved by the use of an adequate radar installation will pay for its cost in a comparatively short period of time.

d. The complete requirements for radar intended for lake, river and passage navigation which must be met by equipment taking the fullest advantage of the present state of the art are severe. However, these requirements are not radically different from those which should be met by an all purpose radar for general navigation on the oceans or elsewhere.

e. For accurate position finding and navigation in rivers and passages high resolution and maximum range in picking up buoys and other aids to navigation are required. It does not appear that, for the Great Lakes at least, this severe requirement can be met on a practical basis on frequencies below the 10,000 megacycle band.

f. Obviously, a radar designed to meet the severe specifications necessary to produce a set for all purposes will be more expensive than a set which only

partially meets these specifications. However, this increase in cost is small when measured in terms of the superior capabilities and greater usefulness of the more adequate equipment. If a radar manufacturer attempts to reduce the cost of his product by eliminating certain functions, then the value of his product is, in all probability, reduced in far greater proportion than the price he must charge for it.

40. In addition to the immediately tangible results of the Great Lakes Radar Operational Research Project which find expression in the conclusions set forth in this paper and the more complete report it is hoped that these studies will indicate the desirability of a similar attack in the application of new scientific knowledge to large scale use in various peacetime industries.

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INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN · · · APRIL 28-MAY 9, 1947

RADIO NAVIGATIONAL AIDS FOR SMALL CRAFT

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ABSTRACT

This paper presents a non-technical analysis of certain existing marine radio navigational devices and systems, together with their present and prospective possibilities and limitations as applied to the needs of small craft.

A division is drawn between pleasure boats and small commercial vessels, in considering their respective requirements for these navigational aids.

Specific problems encountered by the vessel owners, research engineers, and equipment manufacturers, are presented, together with, in some cases, suggested solutions.

RADIO NAVIGATIONAL AIDS FOR SMALL CRAFT

Introductory

1. For the purpose of considering the needs of electronic aids for small craft, such craft must be divided into two categories, namely, those engaged in any marine operation the object of which is to produce revenue, and those operating without this objective, such as pleasure boats. It is impossible to discuss the subject without giving recognition to the wide distinction that lies between pleasure and commercial vessels in their respective needs. The pleasure craft operator naturally is concerned with the safety of his vessel, but he is not necessarily going to be enticed into the expenditure of any considerable amount of money for devices by the arguments that might influence their purchase by the commercial ship owner. The latter can compare the cost of installation and operation against the potential monetary savings to be derived, and thus can quickly determine whether the device is indispensable to his vessel. Therefore, let us first consider the needs of small boat owners, and by that I mean pleasure craft not over sixty-five feet in length. In the United States we have at present approximately 430,000 of these boats registered, with many thousands of others documented. Surely this offers a large and fertile field in which to cultivate better safety at sea, and it is also one which the progressive manufacturer should keep in mind when planning the work of his research laboratory.

Radio Telephone - (Pleasure Craft)

2. It would appear that far too little attention has been devoted to research and development in the field of radio communications. A reading of the report of the IMRAMN meeting in London last year disclosed that there has been an excellent utilization of radio telephony and radar in connection with navigation and docking in the Mersey River at Liverpool. Also, radio communication was briefly touched upon by Sir Robert Watson-Watt in his summarizing of the results of that meeting. In his summation he admitted that there had been a neglect of radio communications due to the necessity for a devotion of attention to radar and navigational aids. Quoting from his speech, he said, "Had we spared 20% of the effort from these navigational aids to effecting a corresponding revolution in the communication of intelligence over radio channels, we would have made another gift to the transport world that would have been comparable in importance to that which has been conveyed by the navigational aids."

3. In reading that speech I find that a distinction was made between radio communication and navigational aids, yet to my mind there should be none. And I add, that I believe a radio 'phone to be one of the most important navigational devices with which a small boat can be equipped. As I understand the function of an aid to navigation, it is intended to bring the vessel safely to its destination. However, if the boat-owner finds his boat to be in a condition of distress such as might be caused by motor failure, damage to rudder or propellor, thereupon these other aids - compass, sextant, direction finder, radar, loran - these have no value to him, but his radio 'phone becomes a navigational aid through which he can summon assistance to bring him safely to his destination. Toss overboard the rest of his aids, but leave him his 'phone - his one link with safety. He doesn't even need to know his location in calling for assistance, for the D/F shore net can attend to that phase - can locate him and within a few moments furnish an accurate fix to rescuing craft.

4. So, for the small vessel, whether being operated for pleasure or profit, the radio 'phone is one indispensable device with which each boat should be equipped. Boatmen are rapidly recognizing this, as witness the statistics supplied by the Federal Communication Commission. In 1940 there were approximately 2,000 radio telephones in operation on United States civilian craft. Last year, during the one month of September, there were more than 500 radio telephone licenses issued. In addition to the models now available, there would appear to be the need for a small, inexpensive, single channel radio phone for very small craft. It should have low power-consumption and be sturdy and well shielded against salt water corrosion. Such a set would be designed to communicate only with the Coast Guard, and its use would be restricted to emergencies. There should be a ready acceptance of this by owners of small boats, especially those boats with single motors.

<u>Medium Frequency Direction Finders</u> - (<u>Pleasure Craft</u>)

5. Again using the premise that the value of a navigational aid to the pleasure boat owner is measured in terms of the assistance it will afford him in arriving safely at his destination, it would appear that next in importance and practicality among electronic navigational devices is the shipborne medium frequency direction finder. This is not by any means a new device, for twenty-five years ago it was being accepted by yachtsmen as a useful aid. It is perhaps unfortunate that the shroud of mystery which enveloped the wartime development of other electronic aids, stimulated the imagination of the average boatman to where he now

expects miracles from these aids, and overlooks the exceptional worth of the direction finder as an instrument with which to check other methods of piloting or navigation, or as a means of obtaining bearings in rain, fog or snow.

6. It would be interesting to know the percentage figure representing the relationship between the total number of small boats in use and those equipped with radio direction finders. I venture to hazard the statement that the surface here has scarcely been scratched. In the more than two decades in which it has been available, why has there not been a more general use of this position finding system on small craft? Frankly, I believe that the manufacturers were not alive to the sales potentialities of this field, and the technical and production engineers, following the line of least resistance, directed their attention to the development and production of devices for larger vessels. Had stress been given to simplifying the equipment, reducing size and weight and lowering price, there would today be many more small craft found with direction finders aboard.

7. From information at hand it would appear that there has been very little development in radio direction finders for small craft during recent years. Available rotable loop, low frequency types present nothing new over pre-war design. Some instruments now have a magnetic compass incorporated within the loop, making it possible for the navigator to coordinate the radio bearing with the ship's steering compass, which would appear to be a desirable refinement particularly on a small boat having limited crew personnel. Another improvement is the fixed loop automatic direction finder using electronic switching and meter type indication. Present prices for this type of device do not indicate it will be readily accepted by owners of small craft. However, its desirability is unquestioned, for it furnishes much greater ease in obtaining bearings and provides freedom from ambiguity. To encourage the production of these the United States Coast Guard has recently modified many of the prominent radio beacons so they will emit continuous radio frequency energy during the period they are transmitting, with keyed modulation for the characteristic identifying signal. Previous practice was to key the radio frequency carrier so that between signals the automatic direction finder indicator would not hold on a steady bearing.

8. The operation of radio direction finder receivers is comparatively simple. Some models have a mechanical compensator to automatically compensate for deviation, and although D/F bearings are arcs of a great circle and require no correction when plotting on gnomonic charts, the same bearings can also be used without correction on Mercator charts for distances of less than fifty miles.

Currently manufactured models are sturdy in construction and well sealed against salt water corrosion, both of these features being desirable on small boats owing to the rough treatment they are apt to receive. However, it has been found that the purveyors are not always prudent enough to impress upon the buyer the necessity of meticulous installation with concurrent care in compensation and calibration. As a consequence, numerous boat owners have quickly become dissatisfied, not knowing until too late that the instrument was in error.

9. Some manufacturers have taken a step in the right direction and have given added appeal to the direction finder for the yachtsman, by the incorporation of circuits for shifting to broadcast and communication frequency bands. In this way a navigational aid, not only brings in M/F directional bearings but also serves as a means of receiving entertainment on the standard broadcast band of 550-1500 kcs, as well as news and weather reports on the 2 to 3 mc communication band. The question might be raised as to why a navigational device should also be called upon to emit the strains of a dance band, and the answer is "space". Never yet has a small craft been designed with sufficient space to satisfactorily hold all of the yachtsman's gear and equipment, and that is why I made the statement that a step had been taken in the right direction in manufacturing this combination receiver. Let us hope that it is only the first step of many, for there would appear to be no reason why there should not be fabricated a combination of direction finder and radio telephone transmitter-receiver. And I'll even go beyond this and venture a prediction (and I'm informed by technicians that it is within the realm of possibilities) that a depth finder could also be included in the combination.

Depth Finders - (Pleasure Craft)

10. The necessity of a depth finder for small pleasure craft might be questioned. Its value from the standpoint of safety in navigation is too well recognized to dwell upon, but except on the larger yachts there has been no wide acceptance of this device due to the fact that the price has appeared high in relation to the advantages to be obtained. Pleasure craft engaged in sport fishing, however, possess a distinct advantage through the utilization of a depth finder. And parenthetically may I say, at this point, that in any consideration of the needs of small craft, those of the sport fishing industry must not be ignored. According to recognized authority, the sport fishermen of the United States, in the pursuit of this pastime, expend one billion, two hundred thousandsof dollars each year. It is estimated that there are in this country twelve million fishermen, six million of them licensed, and that these devotees have over six billion

dollars invested in boats, for the operation of which they spend six hundred million dollars yearly. The State of Florida alone estimates that its piscatorial attractions bring two million fishermen into the state each year, and no inconsiderable number of these visitors charter local sport fishing boats for which they pay a daily fee of from $45.00 to $100.00. These charter boats may well be included in any consideration of vessels operating for revenue, and navigational aids such as direction and depth finders which will assist their operators in reaching fertile fishing grounds are devices with which these boats should be equipped.

Radar - (Pleasure Craft)

11. The average yachtsman is interested in radar and position finding by means of radio as applied to navigation at sea. Obtaining a fix from celestial bodies from the relatively stable bridge of a ship is quite a different matter from attempting the same thing from the storm-tossed deck of a small boat. Also, of interest to the yachtsman is anything which may add to the safety of his vessel, and now, with but a modicum of information regarding the advantages of shipborne radar equipment, he wants to know how, when and where he may secure for his boat this all seeing electronic eye through which he may discern approaching ships or navigational dangers irrespective of any impediments to optical vision, such as fog, rain or darkness.

12. However, it appears extremely unlikely that there will be any extensive installation of radar aboard small pleasure craft for some time to come, notwithstanding the added factors to be gained by the use of this micro-wave radio detection system. The high cost of the device will deter most boatowners from its purchase, although it will be installed on some of the larger yachts by owners who recognize its high value as an anti-collision and navigational aid, and are willing to pay a price which is today beyond the reach of the average small boat owner.

13. Again, this matter of cost to the boat owner leads one to wonder whether the radar manufacturers are not neglecting a fertile field in apparently ignoring the needs of small craft. How many present owners of expensive automobiles advanced to this ownership through a succession of progressively higher priced cars? And how typical it is for the owner of a small boat to sell it and acquire a larger and more expensive one. Electronic navigational aids to the average pleasure boat owner are new, mysterious and untried gadgets, and he will conduct operational research upon them only when their cost has been considerably reduced from the present level. Therefore, why should not efforts be expended in the development of a low priced radar, even though there has to be a sacrifice of such desirable qualities as high resolution, great precision and low minimum range? If it were procurable, there would undoubtedly be

a demand for such a radar, designed primarily for use as an anti-collision device. It should be small in size, light in weight and require a minimum of power. The antenna could be a simplified Yogi type rather than the parabolic, and might be manually operated. Although a P.P.I. scope would be preferable, an A scope would suffice. While it is true that the instrument as a navigational aid would have very definite limitations, it should be useful in a distance range of 3 to 10 miles down to 500 yards, with a range accuracy of 300 yards and a bearing accuracy of 5 degrees and on targets from the size of a good-sized buoy. Not only would it have a value in the avoidance of collisions with obstacles at sea, but it would also serve as a means of acquainting the yachtsman with the potentialities of this member of the electronics family. Such an association might well create in him a desire for the acquisition of other and better members of the same family.

Commercial Vessels

14. Up to this point we have been contemplating the possibilities of electronic aids to navigation, but only as applying to pleasure craft. Now let us consider them in the light of their needs and value to small vessels being operated for revenue - such vessels as harbor craft, tugs, barges, ferries, small coastal freighters and passenger ships, small tankers, fishing boats and trawlers. While the owners of these vessels are concerned with the safety of ship, cargo, crew and passengers, there are other ponderables to be considered when arriving at a decision as to whether any or all of the radio navigational aids may be appropriate for a specific ship. A delayed arrival in port may mean but little to the pleasure boat owner, but it may spell the difference between a profit or a loss to the owner of a commercial vessel. The disastrous result of his retarded voyage will show up in the red figures upon the ledger, therefore, to the ship owner operating for revenue, it is a "must" that he investigate the possibilities of these navigational devices in order to determine whether or not they are indispensable to him, irrespective of their cost.

Radio Telephone - (Commercial Vessels)

15. The radiophone has become recognized as requisite equipment not only for transoceanic vessels, but for harbor, coastwise and fishing craft. Frequencies being used by these small vessels are in the 2 to 3 mc band with power of the order of 5 to 100 watts. Operation has been simplified, quartz crystal-control of transmitter frequencies being customary rather than master oscillator, thus permitting the operator by means of a switch to change from one frequency to another, and to resonate the antenna for each, for the set's inherent qualities

do not permit it to stray from the prescribed frequency tolerances. Refinements such as the selective ringing system and the "VODAS" circuit are being more generally used, and power consumption has been reduced through the use of improved but smaller tubes. Quick heating tubes are also an improvement over the old type.

16. Already the frequency bands allocated to radio communication are bursting at the seams and it becomes increasingly obvious that steps must be taken to relieve the overburdened channels of ship-to-ship and ship-to-shore communications on the 2mc band. VHF transmission on the 152-162 mc band may be the answer, yet since this is only useful on distances equal to or a little greater than the line of sight, its use at the present stage of the art must be restricted to harbor craft or those operating within 25 to 30 miles of the coast, leaving the MF and HF radio telephone spectrum space available for craft that operate at greater distances at sea.

Depth Finders - (Commercial Vessels)

17. Whereas it may be felt that the depth finder is a navigational aid of limited use, there is one type of commercial vessel upon which it is invaluable equipment, and that is fishing craft. By the use of this aid the fishermen are enabled not only to more quickly locate their fishing grounds, but actually to catch more fish through the underwater knowledge which is conveyed to them by this instrument. An indicator gives them the exact depth of the water beneath the keel and a recorder can supply continuous graphs showing the nature of the sea bottom and its contours. Exhaustive tests also have demonstrated the value of depth finders in actually detecting schools of fish. General development of this aid has been toward simplification, decrease in size, weight and power consumption. Although not a cheap device, its cost should not be a deterrence to its purchase by the fisherman, for it will probably return its cost, many times over.

Medium Frequency Direction Finders - (Commercial Vessels)

18. Medium frequency direction finders have been found aboard small commercial vessels for many years, and their worth as a position finding system is well recognized. The owners and operators of these ships, too, have heard stories of the miracles of the new war born electronic systems, and now wonder whether their direction finders are headed for the junk pile. It would appear that their minds should be set at rest, that they should be informed that the ship borne M/F-D/F is still recognized by authorities as an invaluable position fixing instrument particularly for coastal navigation or when approaching harbor, also that there is no immediate danger of its being ruled out by reason of obsolescence.

19. It is not my understanding that medium frequency direction finding has ever been accepted, per se, as a navigational system. On the contrary it has been an adjunct to, and a check upon, other systems. Recent developments have not changed this picture, and although it is expected that later models of receivers will contain refinements of new components and circuits, and that the presently available facilities of shore beacons will be improved and extended, nevertheless this radio navigational system is destined to be looked upon for some years to come as an indispensable aid to the mariner.

Radar - (Commercial Vessels)

20. High prices are limiting the use of radar by pleasure boat owners, but this is not a factor in the case of commercial vessels, for here again we find that the benefits which may accrue far outweigh any possible consideration of cost. The simple, inexpensive radar I have suggested for the yachtsman as an anti-collision device would not meet the demands of the owners or operators of small commercial ships. Radar is no longer a mystery to them, and already they have learned to expect it to serve not merely as an anti-collision device, but also as a superior, I might even say "spectacular" navigational aid. And radar IS spectacular in its ability to see through storm, darkness and fog. Ships, channel markers, buoys, natural topography, are all clearly indicated on the screen of the cathode-ray tube, or "scope", whether within 50 yards or 25 miles away, and the ability to detect these, regardless of weather, is a matter of paramount importance to the ship operator in his maintaining of schedules.

21. Current commercial radar models operating in the centimetric super high frequency band, with narrow horizontal beam, are a great improvement over the lower frequency wartime radars, and provide excellent P.P.I. presentation, with reliable discrimination and remarkably accurate range and bearing resolution. Scopes are equipped with both fixed and movable azimuth scales, and a turn of the switch, without any adjustment, will change the presentation from one to the other of true or relative bearing. When a north stabilized true bearing presentation is shown, relative bearings are simultaneously indicated by the luminous ships heading marker on the scope. Progress has been made in suppressing or minimizing the undesirable echoes known as "clutter" and consisting of back-scattering radiation from unwanted targets such as rough seas, snow or rain.

22. In addition to the interest displayed by the ship owner in primary radar, the development of secondary radar is a matter of concern, especially to the owner of the little ship. Micro-wave radio beams used for radar transmission, and close in the spectrum to light waves, follow to some extent the same laws. Height of antenna largely deter-

mines its line of sight, the radar horizon in miles being roughly 1.22 times the square root of the antenna height in feet. Therefore, it becomes obvious that the small vessel with short antenna is to some degree handicapped in attempting to make radar identification of natural topography or navigational landmarks. Assistance may be supplied by radar aids or beacons, with the responder type as first choice. The worth of its instantaneous range and bearing information cannot be denied, but present high costs, plus fiscal economy, may preclude their extensive installation. In lieu of this, it is felt that some simple echoing device should be provided such as the corner reflector (and the genius should be thanked who selected this appellation, instead of forcing us to refer to it as a "right tetrahedron with its equilateral surface removed"). These corner reflectors could be supplied with the means of conveying identification through their arrangement in geometric pattern. Undoubtedly this method will be improved upon, in fact there would appear to be the opportunity for considerable research in the development of suitable radar beacons, both active and passive. Also, it is possible that some manufacturer may discover that an inexpensive shipborne interrogator-indicator for use with responder beacons may be designed for use on small craft.

Position Finding Systems

23. In discussing position finding systems for pleasure craft, medium frequency direction finders and radar were considered. However, I purposely did not mention any of the other electronic systems by which the navigator may determine his location for I felt that there were reasons why one or more of these systems might be applicable to the needs of both pleasure and commercial craft. It is not within my province to attempt any technical discussion of the relative merits of the major systems evolved from wartime research, further than to compare their navigational operational characteristics.

24. While amazingly accurate results are being obtained in position finding through the utilization of presently available electronic navigational systems, it must be conceded that the art is still in swaddling clothes, that the future will bring many added refinements and improvements, and in fact many of the devices now in use will become obsolete. However, the ship owner should not wait for ultimate perfection, but, by his use of equipment which he can now obtain, he should participate in its development and improvement. Laboratory research and operational research should advance hand in hand. And, as research continues, as it will, until such a time as one particular electronic navigational system surmounts above all others to world wide acceptance, it would appear that ship owners might well be deriving the advantages now offered by Loran.

25. To enumerate some of the advantages of Loran - it permits the navigator to determine his position accurately at distances from the transmitting stations as great as 750 nautical miles in the daytime and 1400 miles at night, and under almost any condition of weather this accuracy will be as great as is customary with good celestial observations. Operation is simple, no specialized personnel being required. A navigator can be trained in the technique of Loran reception and interpretation in as little as one day. The time required to obtain a fix is short, usually from two to three minutes. Fixes obtained by Loran are independent of other navigational instruments such as the chronometer, sextant or compass. Readings obtained from the receiver are interpreted in conventiel coordinates by the use of Loran charts published by the U. S. Hydrographic Office. No compensation or calibration of the set is required, for the system is so designed that the internal components of the equipment provide the means for self-calibration. The network of transmitting stations erected by the United States Coast Guard now affords practically continuous coverage along both coasts of North America and over considerable of the sea traffic routes of the world.

26. A commercial model of Loran receiver is extremely compact, measuring approximately 14 inches square by 25 inches deep, and weighing from 75 to 125 pounds. A single wire antenna suffices, and even on small boats the existing power supply will meet requirements. The cost is within the reach of all, since a Loran receiver can be bought for the price of a good home radio set.

27. The compactness of the instrument, its accuracy, reliability, ease of operation and low cost would indicate that no commercial vessel or pleasure craft, requiring long or medium range position data could afford to be without it.

28. Vessels operating within short distances of the coast ordinarily will not obtain as accurate Loran position information as those operating at long range, since it is an inherent characteristic of a long range hyperbolic navigational system that attempts to improve coastal coverage will result in deterioration of long range coverage. The physical arrangement of Loran transmitting stations is such that certain areas provide excellent coverage even for short range, and vessels operating in these areas, such as fishing boats, will find Loran enabling them to locate off-shore fishing grounds, regardless of weather, within a quarter of a mile.

29. Discussing depth finders, I mentioned their value to the fisherman, now we hear from the masters of vessels in the fishing fleets of the successful results they are obtaining through the use of Loran. Last year a Loran receiver was installed aboard one of the large trawlers of the General Seafood's Boston fleet, and regarding it the ship's veteran master, Captain Iver Carlson, made the statement

that he considered Loran as the best thing invented since the depth finder and that with it he could obtain a 3 line fix within five minutes. Additional trawlers have since been similarly equipped and their skippers have found it possible to become familiar with the system and learn its use within a few days. They report that the speed and simplicity of position finding permits a fix to be taken whenever the net is set out, and again when it is hauled about an hour and a half later, thus they know the exact distance travelled, which is a great help in remaining on the best fishing grounds.

30. In general, at any point along the coast, one excellent Loran line of position may be found, with one or more intersecting lines that may or may not form an angle sufficient to give a good fix. Upon leaving the coast the fix accuracy improves while the accuracy of the short distance aids deteriorates. For those sections of the coast where good Loran coverage exists, this system offers one of the best and most reliable means of position finding.

Power Supply

31. Any discussion covering the use of electronic equipment aboard small craft must give recognition to the woeful inadequacy of power supply. Boat architects and builders should so design their craft that suitable space would be allocated for the installation of radio navigational equipment, and also provisions should be made for sufficient battery capacity and auxiliary power to meet the demand not only for these electronic aids, but also for refrigeration, ventilation, lighting, heating, clutch and rudder controls, winch operation and other electrically performed functions. Here again is a fertile field for the progressive manufacturer, for the boating public is crying for an auxiliary power device which will be compact, sturdy, light in weight, quiet in operation, reliable, that will not overheat in restricted spaces, and will possess inherent freedom from hazards of fire or explosion.

Conclusions

32. Owners and operators of commercial ships should be interested in investigating the potentialities of electronic navigational devices and systems as they may apply to the needs of a specific vessel, and both commercial and pleasure craft should consider the possibilities of these radio aids insofar as they may add to the safety of their vessels.

33. Manufacturers of electronic equipment should be alert to the opportunities being offered them for a wider distribution of their products in the pleasure craft market. However, they must give recognition to the limitations of space and power available on small boats, and they should understand that a device must be so designed that it can be produced to sell at a price which will bear a reasonable relationship to the value of the vessel upon which its installation is contemplated.

34. It is my opinion that among owners of small craft of the United States resentment would be engendered by any promotion of a position fixing system operating upon a fee basis. Being obligated to pay a charge for obtaining a fix would be about as popular as having to pay to use the beams from a lighthouse, or to receive directions from a traffic policeman.

35. I spoke ofthe necessity for laboratory research and operational research advancing hand in hand, and any progress in the development of electronic navigational aids should be of vital interest to the Board of Marine Insurance Underwriters. Increased utilization of these aids will mean lower loss ratios, a matter of weighty concern to the insurance companies, and lower loss ratios should result in lower rates - an important concern of the boat owner. Let us hope that the insurance companies will have enough vision, and faith in the equipment, to believe that its use will eventuate in a decrease in loss ratios, and that this will permit rates to be reduced now wherever installations are made. This should serve as a stimulus and offer encouragement to the owner to install the aids aboard his vessel, especially since the premium saving might eventually pay for the equipment.

36. Although owners of commercial and pleasure craft of the United States are undoubtedly willing to acknowledge the apparent value of the new electronic devices and systems, they will resent any attempt by constituted authority to force the installation of these through legislative fiat. I believe vessel owners have a profound respect for the governmental agency that is at present charged with the responsibility of initiating and enforcing measures connected with the safety at sea of vessels, crews, cargoes and passengers. They look to this agency to continue its progressive program, and do not expect it to recommend any legal requirements for additional equipment until such has been tried, tested and proved through prolonged and exhaustive operational research.

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IMMRAN DOC. 12

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN. · · · APRIL 28-MAY 9, 1947

U. S. MARITIME COMMISSION ELECTRONIC NAVIGATIONAL TRAINING PROGRAM

- By -

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ABSTRACT

This paper stresses the importance of training in the comparatively new field of Electronics in the merchant marine. It presents an outline of the Electronics Training in Navigation given by the United States Maritime Commission:

1. To Cadet-Midshipmen at the U. S. Merchant Marine Academy at Kings Point.

2. To Merchant Marine Officers, at U. S. Maritime Service Schools at New York and San Francisco.

3. To Radio Officers, at the U. S. Maritime Service Training Station at Sheepshead Bay. (Maintenance of Equipment Only)

A general outline of the training program is given in each case, with the scope indicated, as a preparation for the visits which are included in the program for the Delegates to this meeting.

U. S. MARITIME COMMISSION
ELECTRONIC NAVIGATIONAL TRAINING PROGRAM

1. The modern navigator, in whatever service he is engaged, is looking more and more to the scientist to help him in his task. The new electronic devices developed during the war can undoubtedly help to make the sea a safer place for the transportation of passengers and the products of peace, but they must not be allowed to be misused by untrained personnel. The personnel factor is the variable quantity in the equation, and even when the machines which man has made are working perfectly, a careless or negligent navigator may reach a wrong conclusion, and the answer instead of safety, may spell disaster. With this in mind, we have set up within the U. S. Maritime Commission's Training Program certain courses in Electronics.

2. In order to give you a "radar's eye" view of these particular courses, it is necessary for me to fill in briefly for you the background, and then I will proceed at once into the detailed picture. In 1938 legislation was enacted which gave birth to the modern system of merchant marine training which we now have, and which was so largely responsible for manning our huge war born merchant fleet of 60,000,000 tons. Since the inception of our Training Program in 1938 to April 1, 1946, we graduated from our Training Units a total of 271,646 men in all branches of training which includes officers and men, both deck and engine, radio operators, pursers, hospital corpsmen, stewards, cooks, bakers, river pilots, ship carpenters, pumpmen, and electricians. Of this number, about 200,000 were new men in the Industry and the remainder, already in our merchant fleet, were upgraded to higher positions. In addition, about 3,000 officers and men were trained by the United States Maritime Service for the Transportation Corps of the Army Service Forces and the other Services.

3. I have given some statistics relative to the part which our training system played during the War which has just ended, but I should like to mention the long range permanent concept upon which this system is based. The training system is operated by the Training Division of the U. S. Maritime Commission, which is mandated by Congress to supply trained and efficient personnel to the American merchant marine.

4. The Training Division has three major components, the U. S. Maritime Service, and the U. S. Merchant Marine Cadet Corps and the State Maritime Academies.

5. First the United States Maritime Service. Its ranks and grades correspond exactly with those of the Navy and Coast Guard, as does its pay and allowances. It is responsible for the training of seamen, firemen and oilers, messmen, cooks and bakers, radio and radar men, ships clerks, pharmacists and hospital corpsmen. It also trains diesel engineers, turbo-electric engineers, high pressure geared turbine engineers, junior engineers, pumpmen, carpenters and electricians. Another, and one of the most interesting of the many phases of training is the upgrading of officers already at sea, and the upgrading of officer candidates from experienced unlicensed men.

6. The United States Merchant Marine Cadet Corps trains officer cadets, called Cadet-Midshipmen. These high school graduates are selected from the nation at large, on a state-quota system, as a result of national competitive examinations. They are first given basic training for one year, and thence proceed to sea as Cadet Midshipmen for another year, they then return to our Merchant Marine Academy at Kings Point, New York, for two years of advanced training. Upon graduation and upon successfully obtaining a merchant marine license as third officer or third assistant engineer they are commissioned as reserve Ensigns in the United States Maritime Service and also in the United States Navy, and recently Congress has authorized the award of the Bachelor of Science degree to our graduates who successfully complete the four year course.

7. Officers are also trained by the State Maritime Academies. There are five of these State Academies. They are located in, and operated by the States of Maine, Massachusetts, New York, Pennsylvania and California, with the aid of the Federal Government. Their graduates are similarly commissioned as reserve Ensigns in the United States Maritime Service and also in the United States Navy.

8. All of this training is aimed at making, and keeping, the United States Merchant Marine on its toes, up-to-date, speedy, safe and efficient.

9. It will be our pleasure to show you our Merchant Marine Academy at Kings Point and our Training Station at Sheepshead Bay, so I will only outline briefly the scope of the electronics training given there.

(D)

10. Cadet-Midshipmen/of the U. S. Merchant Marine Academy are given a course in "Electronics" of eighteen weeks duration, four hours each week. This course includes electronic aids to navigation, as well as communication receivers and transmitters. Aids to navigation include loran, radar, the radio direction finder and the fathometer.

11. The first requirement in training in electronic aids to navigation is that the Cadet-Midshipman learn to operate the equipment. He learns by actual practice, the necessary manipulation of the controls. It is desirable that practical conditions be duplicated as far as possible.

12. To this end we have installed and have operating in the laboratory:

four loran receiving sets of Sperry and Radiomarine manufacture

two radio direction finder sets of Radiomarine and Marine Bludworth manufacture

also an operational demonstration of a Submarine Signal Company fathometer. A radar set, Navy model SL-a is being installed at the present time. This equipment is similar in all essential respects to commercial models being installed on merchant ships.

13. For preliminary loran training, when ideal conditions are desirable, local, artificially-generated signals are used. Two pairs of simulated loran transmissions comprising four separate signals are available for operational practice. As the student progresses, he is required to obtain a time-difference reading from an actual loran station pair. This is pair 1L0, the master station at Nantucket, the Slave at Hatteras. The reading obtained is approximately 4420 microseconds for the location at Kings Point. Although the signals are very weak due to land intervening between the transmitters and the reception point, the lines of position consistently plot less than one mile from the actual location. For advanced practical training, a night session is held for observation and use of sky wave signals. Sky wave signals from several actual station pairs along the Atlantic Coast are receivable.

14. Practical work in radio direction finding includes the taking of bearings on the transmitter at Newark Airport. Although this is not a standard radiobeacon station, it affords strong signals receivable on the radio direction finding equipment.

15. Cadet-Midshipmen learn from the use of this transmission how to recognize the characteristics of a reliable RDF bearing. Practice on actual RDF stations is afforded by the transmissions of a group on 286 kilocycles per second, Ambrose Light Ship, Barnegat Light Ship, and Fire Island, and also from Cape Cod. Signals from Barnegat and Ambrose are quite weak due to the distance of the transmitters and transmission paths involved.

16. The location at Kings Point is particularly good for the reception of loran signals and radio beacon signals. Transmissions representing both good conditions and poor conditions are available. Perhaps those representing poor conditions are the most valuable,

17. The radar antenna when installed will be on top of BOWDITCH Hall, at Kings Point on the north shore of Long Island. It will be possible to observe on the oscilloscope screen, echoes from sea-going vessels in Long Island Sound up to approximately thirty miles in range. In addition to being indicated on the oscilloscope screen, targets at short range will be visible on clear days from the operator's position. This feature is expected to be valuable in teaching the identification of a target from its scope indication.

18. Of all the navigational aids taught at the Academy, the most difficult to set up in a manner simulating practical operation is the fathometer. We have not yet worked out a method of sending a supersonic signal through a few hundred feet of sea-water and getting a reflection back to the fourth deck of BOWDITCH Hall!! We have compromised with a method by which the supersonic signal is transmitted in air. The signal travels the length of a passageway and is reflected back to the fathometer receiver. Operation of the equipment is essentially the same as if the installation were more nearly standard.

19. Training in elementary operation of electronic aids, while important, is only a part of the necessary background Cadet-Midshipmen must have to serve efficiently. The well-trained mariner of the future must know a great deal more than the mere sequence in which switches and knobs must be operated

to get a desired result. The successful use of electronic navigational aids rests on an understanding of the principles by which the various systems operate.

20. Understanding of principles is necessary in order that the mariner may:

(1) Evaluate the reliability of the information presented.

(2) Get the maximum aid from the system even under unfavorable conditions.

(3) Correlate navigational information obtained from electronic aids with that obtained by celestial methods.

21. For example, loran lines of position possess varying degrees of accuracy depending on location, signal strength, type of signals received and other factors. Under best conditions a loran line of position can be depended on to within 500 yards. Under extremely poor conditions, loran lines may possess an uncertainty of as much as 15 or 20 miles. The navigator must be able to estimate the accuracy of loran information and correlate it with other navigational information to arrive at the best possible estimated position.

22. To understand the use of electronic navigational aids, the mariner must understand:

(1) The principles of radio transmission and reception.

(2) Propagation of radio energy through space.

(3) The effects of the ionosphere.

(4) Atmospheric noise and interference.

(5) Pulsing techniques.

(6) Functions and characteristics of electronic equipment.

23. The emphasis here, as you see, is on the external factors. The factors which vary with time, location, frequency, and the particular system employed. These are the variables of an electronic system. These are the factors which determine the decisions the navigator must make.

24. Circuit components and circuit operation are of minor importance to the deck officer. This is the province of the technician. The deck officer, instead, is concerned with the characteristics and overall function of equipment, rather than with a detailed analysis.

25. Fortunately, these basic ideas essential to the proper use of aids to navigation, are the same ideas essential to the proper use of radio communication systems. The range of a radio transmitter, for example, depends on the same factors, such as power, frequency, path of transmission, time of day, as does the range of a radar or a loran transmitter. Likewise, the minimum strength of signal that can be received depends on the same factors for a communications receiver as for a radar or a loran set.

26. Therefore, an important phase of the electronic navigational program at the U. S. Merchant Marine Academy, is a study of the elements of radio communication. Emphasis is on the variable, external factors plus equipment characteristics and overall equipment functions.

27. To this end, lectures and training films are presented in the classroom, together with assignments from the text "Understanding Radio" by Watson, Welch and Eby. In the laboratories, receiver and transmitter models are demonstrated. Equipment functions are often illustrated by the use of the cathode ray oscilloscope. Commercial receivers and transmitters including lifeboat models are available, not only for specific operational practice, but for illustration of the underlying principles of communication.

28. To summarize, the Electronic Navigational Training Program at the U. S. Merchant Marine Academy consists of:

(1) Actual use of all the important electronic aids to navigation under conditions approaching practicality.

(2) Study of the essentials of electronics and of propagation of radio energy.

29. In short, it is a background on which to build experience,

practical information necessary. The course has been moulded in such a way that the students will see the danger of superficial knowledge. Standards of equipment performance and a few installation pointers are covered so that the operator may check his set for peak performance.

35. The LORAN training equipment in San Francisco consists of three different types of LORAN receivers. There are fourteen DAS sets, a type used by major naval vessels during the war, and seven DBS receivers. This latter type of equipment is now being installed in fifty-four (54) vessels by the Maritime Commission. The school also boasts one DBE set which is an unusually fine commercial version of the shipboard gear. Two synthetic pulse generators round out the LORAN equipment picture in San Francisco.

36. The New York unit has ten DBS sets; two are in operation and eight are enroute to the school. Three DAS receivers and two synthetic pulse generators complete the equipment at the east coast location. The fact that several types of equipment are available for student training at both schools makes these courses extremely adaptable to fit the needs of the student, irrespective of what model equipment he might actually operate.

37. In the RADAR courses a great deal of importance is attached to pointing out typical scope distortions as manifest on surface scan RADAR. One of the most ingenious of all the Navy's training devices has been used to show this, as part of the study of RADAR scope interpretation. This device is the VPR trainer -- VPR being short for Virtual, Plan-Position-Indicator, Reflectoscope. A chart to the same scale as the RADAR scope picture is superimposed on the RADAR pattern and by comparison an accurate idea of the distortions may be detected. The RADAR images have been taken from moving pictures and stills of RADAR in operation aboard ships navigating coastal waters. One might call radar scope interpretation modernistic chart work. In fact, quite a revolution in chart portrayal is already presaged.

38. An unusually comprehensive series of moving pictures are shown and ample time is allowed for reading periods. The available literature includes the most advanced techniques developed by the services during the war.

39. As with LORAN a "behind the panel" description is given of both types of Cathode Ray Tubes used in RADAR and the way in which several of the more common scope presentations are developed and generated.

40. Practical hints on operation of SO military equipment still to be found on many ships are covered. A discussion is also

included on the more common troubles and the nature of their remedies. A great variety of training aids and mock-ups have been developed and used at these schools.

41. The RADAR course in New York City includes a field trip to the U. S. Maritime Service Training Station at Sheepshead Bay where three different types of radar devices are operated.

SHEEPSHEAD BAY - RADIO OFFICERS - MAINTENANCE

42. An electronics training program such as I have described naturally divides itself into two parts; the training of deck officers in the use and operation of the devices, and the training of maintenance personnel in the mechanical and electrical adjustments of the equipment.

43. While there is some uncertainty regarding the relative amounts of maintenance work to be done in port and at sea, the Maritime Service is instructing radio men in the elements of pulsed circuits with the expectation that they will be qualified to perform emergency repairs at sea to radar and loran sets. Some 300 radio operators graduated from this course between March and December of last year.

44. An intensive course of eight weeks'duration was set up in March, 1946, at the United States Maritime Service Training Station, Sheepshead Bay, Brooklyn, New York. Admission to this school is restricted to licensed radio operators with a minimum sea experience of sixteen months. This school has been in operation continuously since its inception date, and has returned to the industry over 370 radio operators qualified through theoretical and practical instruction to make minor repairs, replacements, and adjustments.

45. Before closing I should like to mention our policy in regard to the equipping of our vessels with radio navigational aids. We sponsored the retention aboard Army and Navy vessels returned to the Commission after the end of hostilities, of the radar and loran installations aboard those vessels. All new vessels built by the Commission will be equipped with the latest commercial types of electronic aids.

46. Finally, as Commandant of the United States Maritime Service, I take this opportunity of welcoming you aboard one of

our training vessels, the AMERICAN SAILOR, on her trip to New London, and on her demonstration cruises.

Telfair Knight

REAR ADMIRAL TELFAIR KNIGHT, USMS
DIRECTOR, TRAINING DIVISION
COMMANDANT, UNITED STATES MARITIME SERVICE
UNITED STATES MARITIME COMMISSION

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN. · · · APRIL 28-MAY 9, 1947

A REVIEW OF THE NAVIGATIONAL REQUIREMENTS AND THE RADIO NAVIGATIONAL SYSTEMS AVAILABLE. VIEWS OF THE U.K. DELEGATION.

The Aim

1. The aim of the mariner is to navigate his ship safely and expeditiously over the waters of the earth between one port and another. In order to achieve this aim, the vessel must not during its passage come into physical contact with land, floating or fixed objects, or with other vessels. The vessel must also be safeguarded against damage or inconvenience from weather.

Safety From Contact With Land, Floating and Fixed Marks

2. The mariner's principal concern is that at all times the ship should have sufficient water under her keel to proceed in safety. Any movement of a vessel from one place to another can be divided into all or some of the following stages:-

a. Movement out of the port or anchorage, including passage down a narrow river, channel or estuary, where room to manoeuvre is restricted, i.e. "pilotage waters";

b. Movement near a coast where land may be in sight or dangerous shallow water in the vicinity but where room to manoeuvre is generally available, i.e. "coastal waters";

c. Movement in the open ocean near no immediate dangers, i.e. "ocean passage";

d. Approaching the coast, shallow waters and dangers from seaward, i.e. "coastal waters";

e. Achieving a safe and timely arrival in the desired harbour, i.e. "pilotage waters".

In all these stages except "ocean passage", some form of hazard may be in the immediate vicinity and the mariner's principal requirement is that he should know his position relative to the hazards in order to avoid them. On the wide open ocean, he requires to know his geographical position in terms of latitude and longitude.

3. The requirements for these different stages can now be considered in detail.

a. "Pilotage waters"
(a. and e. above).

In these areas land or shallow water is in close proximity and by the nature of things the mariner is usually required to pass very close to the hazards. Often the water is shallow and in general it is essential to know the ship's position to a high degree of accuracy. This position must also be instantaneously available. The margin of error is small since room to manoeuvre is restricted and the ship can in a short space of time change from a position of safety to one of danger. For the same reasons it is essential to know that the course the ship is making good is a safe one. The requirement is for an accurate position relative to the dangers.

b. "Coastal waters"
(b. and d. above).

When in coastal waters the ship is in more open waters although land or shallow water may still be in the near vicinity. The mariner has, however, greater freedom of movement. Dangers are not normally so close as in pilotage waters and within limits therefore the prudent navigator is able to allow a certain safety margin when clearing these dangers. The requirements are thus much less stringent and it can be stated that provided the mariner knows the extent of possible error in his position he can take this into account in allowing a suitable safety margin. Again, the position required is one relative to the dangers.

c. "Ocean passage".

In this stage the ship may be out of sight of land and in deep water. In most areas there are no

dangers in close proximity. The navigator can allow a reasonable time in which to complete his fix. The mariner requires a position with sufficient accuracy to maintain his desired route, to keep to his time schedule, and to take his ship into the coastal coverage areas at a desired point so as eventually to make an exact landfall.

General Requirements

4. It is convenient to put the above detailed requirements into a more condensed and general form so that the various systems can be compared with these requirements. It must, however, be stressed that any such general statement can be related only to a particular area by considering it together with the geography and, in particular, the charts of the area concerned. The important information to be obtained from the charts is a knowledge of the depth of water and the general arrangement of land and dangers relative to the mariner's position. This immediately indicates the degree of freedom of manoeuvre enjoyed. It is first necessary to define what is meant by danger. Any navigational aid must be equally available for the fishing vessel and the ocean-going liner. It is therefore necessary to consider the deepest draught vessel and so a danger is defined as any part of the sea in which there is less than 8 fathoms of water.

In pilotage waters there is little freedom of movement. The mariner is confined to small areas and normal channels. There is usually little water available and a high degree of accuracy is required. In general terms, therefore, the depth of water will be generally less than 20 fathoms and the mariner is within 3 miles of the nearest danger. He requires to know his position within a circle of 50 yards radius. He also requires to know the course he is making good.

In coastal waters movement will still be restricted by the proximity of land or shallow water but not to such fine limits as in pilotage waters. Normally moderate depths of the order of 20 fathoms to 100 fathoms may be expected and the distance from the nearest danger should be between 3 and 50 miles. The position within a circle of radius $\frac{1}{4}$ mile would provide sufficient accuracy, higher accuracy at shorter distances being desirable and lower accuracy at greater distances being acceptable. On ocean passage the depths are generally over 100 fathoms and the ship over 50 miles from the nearest danger: thus, the requirement can be considerably reduced. A position circle of a radius of 5 miles or of 1% of the distance from the danger (whichever is the less error) is considered to be desirable and to give adequate accuracy.

These general requirements can be conveniently shown in a table as follows:-

CHARTERED AREA	DISTANCE FROM NEAREST DANGER	GENERAL ORDER OF DEPTH OF WATER	ORDER OF ACCURACY OF POSITION REQUIRED TO:-	ORDER OF TIME REQUIRED TO OBTAIN POSITION
Pilotage Waters	Less than 3 miles	Up to 20 fathoms	± 50 yards	Instantaneous position and track
Coastal Waters	3-50 miles	20-100 fathoms	± ¼ mile	3 minutes
Ocean Passage	Over 50 miles	Over 100 fathoms	± 5 miles or ± 1% of distance from nearest danger whichever is the shorter	15 minutes

General Considerations

5. The above are the general requirements which cover the greater proportion of the seas but they can be translated into detailed requirements for any particular area only by studying that area and by taking into consideration a number of other factors. No two areas of the world have exactly the same characteristics. For example, the coast may be "steep to", i.e. the seabed rises in the matter of a mile or two from ocean depths to low water mark; it may be "steep to", with a number of isolated off-lying islands or reefs; or it may be shallow with or without numerous dangerous submerged sandbanks. The strength of tidal streams and currents, the general meteorological conditions over the area (especially the incidence of fog) and the nature of the shipping using the particular area (both as regards the size and type of ships and the volume of traffic) must also be taken into account. It can therefore be concluded that before detailed proposals for any particular area can be formulated an analysis of the factors involved in that area must be carried out.

Application of Existing Aids

6. While there are no radio aids at present in existence to meet in full these exacting requirements, it is considered that certain systems

are sufficiently developed to meet them to a very large extent. Those which most nearly approach the requirements or are capable of being developed in the near future we consider should now be made available to the mariner. We must bear in mind, however, the need for a detailed area analysis before applying these generalisations to any particular part of the world. The mariner is concerned principally with the possibilities of existing aids, but supports the scientist in the development of aids which might have a future application.

a. In Harbours and Approaches - Pilotage Waters

The principal requirement in these areas is that the position and track of the ship, relative to the dangers should be immediately ascertainable. All position fixing systems in use, including visual fixing, involve the obtaining of a position line or position lines by means of an instrument and the transference of these position lines to a chart before the relative position can be obtained: the requirement of position immediately available is difficult to meet. One system which can partly meet that requirement is radar. So long as the dangers are substantially above water, radar will provide an instantaneous relative picture. If the dangers are hidden under the surface of the sea, radar, combined with a Chart Comparison Unit, can also provide a relative picture by direct comparison with the chart, provided that there are sufficient marks (including responders) above water to enable the chart to be lined up with the radar picture; this is often so in the areas under discussion. Radar provides the required accuracy. A position fixing system such as the Decca (See U.K. Paper No. 15) system will also provide the required accuracy and is particularly useful in areas where radar conspicuous marks are few or non-existent but it cannot provide the track unless fixes are continuously plotted on a chart. Since it can provide the position more quickly than by visual fixing, it is considered that a combination of Decca and radar can meet most of the mariner's requirements in pilotage waters.

b. In Coastal Waters

Similar arguments to those given in the preceding paragraphs for the use of radar hold good (within radar range) in coastal waters provided that there

are sufficient identifiable marks above water to enable a fix to be obtained. In a number of areas in the world, however, the above condition is not present and we conclude that it will be necessary to use radar in conjunction with one of the position fixing systems in these areas. The time factor is not so important and a short time lag whilst the relative position is obtained is acceptable.

Of the available position fixing systems, visual fixing is suitable only if permanent marks can be identified and, even so, is not practicable in conditions of low visibility. M.F D/F does not provide the accuracy at the ranges required to provide the necessary cover economically.

Loran approaches the required accuracy in a number of coastal areas, but the extent of these areas is not large enough for the system to be regarded as giving sufficient coverage with an acceptable accuracy for general coastal navigation. Its accuracy is not of the order required for intricate navigation of pilotage waters in harbours and their approaches, and this consideration points to the need for an additional system which might also give the required coverage in coastal waters. The use of Loran receivers may also require a measure of skilled operation and interpretation which might not be available in any but the largest ships.

Consol is primarily a long range aid and would need an uneconomic number of stations to cover adequately all coastal areas to the required accuracy. (See U.K. Paper No. 14).

Gee provides the necessary accuracy only in the best part of its cover, which is a small area, and owing to its limited range is uneconomical. At present the signals have to be lined up and require a measure of skilled operation and interpretation. (See U.K. Paper No. 16).

Decca can provide the required accuracy over an area great enough to provide coverage economically. (See U.K. Paper No. 15). The presentation is simple and does not require a skilled operator. We conclude

therefore that the required aid in coastal waters can be found in a combination of Decca and radar.

c. In Open Waters - Ocean Passage

The requirement in open waters is to obtain a geographical position in terms of latitude and longitude. On most ocean routes dangers are not normally close and the time to take a fix is therefore relatively unimportant. Accuracy to any high order is not an essential. The importance of being able to fix the position at any instant can therefore be weighed against the expense and complexity of the equipment necessary to achieve this. Three systems are at present available which provide adequate range for use on the oceans. These are Standard, Loran, L/F Loran, and Consol. Both these Lorans suffer in comparison with Consol from the difficulty of reading the receivers and in the expense of the equipment. Further, the range of Loran is poor in the daytime, increasing considerably by night, whereas L/F Loran and Consol have fairly consistent long range. Consol has the great advantage that it can be used with an ordinary M.F. receiver which would normally be carried for other reasons and therefore the shipowner has no outlay on additional equipment. In relation to other systems required for coastal and pilotage work, it is considered that the ocean requirement is of low priority. The existing systems do not meet the stated accuracy. If an ocean position fixing system is strongly desired economic considerations would dictate the compromise of using those systems which are primarily set up for the use of aviation. If a number of Consol stations were erected for air use, there would be a clear case for the integration of air and marine interests in this aid. (See U.K. Paper No. 14.)

Safety From Collision With Other Vessels

7. This requirement was fully discussed at the 1st I.M.R.A.M.N. Meeting and it was agreed that ship-borne radar was a firm requirement for anti-collision purposes. In this paper we have shown the additional necessity for radar for navigational purposes. We are convinced that a standard specification which meets both requirements is essential. Reductions in the cost of a radar set achieved by degrading the performance to provide only collision warning in open waters, where freedom of movement is unrestricted, are to be deprecated. The limitations of such a set would not be known to the Master, who might place undue reliance

upon it as a navigational instrument in more confined waters or in areas of high traffic density. This would be undesirable and may be dangerous.

Application to Lighthouse, Buoyage and Harbour Authorities

8. Further problems not immediately connected with the handling of ships but closely related thereto, arise in laying buoys, dredging channels, checking floating marks, hydrographic surveying, and the locating of broken ends of submarine cables; these cannot always be solved by radar; indeed, numerous marks and dangers in European waters are out of sight of land marks. Further, in Scandinavian and Baltic waters and also on the Great Lakes, the coming of Spring entails the replacing of many buoys and marks which have been destroyed by ice or winter storms. The use of an accurate position fixing system in this work is of the greatest value and these problems could be largely overcome by the use of a system of the accuracy of Decca.

The Economic Factor

9. When summing up the ways in which the mariner's requirements can be met, it is important to take the economic factor into consideration. The mercantile shipowner considers costs very carefully in relation to the free service which the mariner has had for years from the sun, moon, and stars, and his eyes; and will not embark on expense in providing special operators, intricate equipment, and special services, unless on balance these are shown to effect savings in operating costs. In other words, the cheaper we can provide adequate aids to meet the mariner's requirements the better the owner will be pleased and the greater the use which will be made of these aids.

Conclusion

10. We now tabulate the existing systems which come near to meeting the requirements, stating the areas in which they will be of most value.

a. Pilotage waters........................	Radar, Decca
b. Coastal waters.........................	Radar, Decca
c. Ocean passage..........................	Standard Loran, Consol, L/F Loran
d. Anti-collision.........................	Radar
e. Harbour service........................	Radar and Decca

14. We conclude that the mariner's requirements are best met by a combination of Radar and Decca in pilotage and coastal waters, and that any requirement for an ocean aid might be covered by the use of Consol stations established primarily to assist the aviator.

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
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CONSIDERATIONS AFFECTING A CHOICE OF RADAR OPERATING FREQUENCIES

- By -

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ABSTRACT

The considerations of radio propagation effects and required angular definition appear to govern the choice of the optimum operating frequency for a navigational radar. The considerations in turn should be based upon the conditions under which the ship operates. The lower frequency is favored for cases where it is most desirable that a reliable maximum range be maintained and the high frequency is favored where high angular resolution with a small antenna is deemed the most important factor.

The choice of a frequency for a microwave radar system is quite a complex problem. Some of the important factors to be considered are propagation conditions for the different frequencies; suitability of available components such as generators of power, detectors, duplexing devices, and RF plumbing; size of antenna system for reasonable gain and desired definition; and the comparative cost of systems having equivalent performances at the desired frequencies.

The purpose of this paper is to set forth some of the present information available concerning these factors which may influence the choice of a frequency. In the short time available it is possible only to touch lightly on these subjects; it is hoped, however, that the net effect will be helpful.

The first factor mentioned is propagation. It is selected as the first to be considered because it is the one factor which will not change as the art progresses or as quantity production makes possible economies of manufacture. It is the one factor affecting a radar system over which we have no control.

Although the present knowledge of microwave propagation is far from complete, there is a considerable amount of information available which can and should be used in the selection of a frequency for any type of system. Reliability of coverage regardless of meteorological conditions is an important consideration for navigational radars. Attenuation of the signals by fog does not seem to be serious within the range 3000 to 9000 mcs. The upper limit for such attenuation has been calculated to be .0045 and .049 db/km/gm/m3 for 3000 and 9000 mcs respectively. For a two-way trip over a 10-mile range the total attenuation would be approximately .15 and 1.5 db for 3000 and 9000 mcs respectively. Attenuation due to rainfall is somewhat more serious. The upper attenuation rates for 3000, 5000, and 9000 mcs respectively are .0006, .0005, and .045 db/km/mm/hr. For a moderately heavy rainfall (20 mm/hr) and a 10-mile range, the attenuations would be approximately .36db, 3db, and 27db for 3000, 5000, and 9000 mcs respectively. The attenuation increases more or less linearly with the rate of precipitation. Since the energy received is inversely proportional to the fourth power of the range we can, in the moderately heavy rainfall, get a reflection at 2 to 3 miles, operating at 9000 mcs equivalent to the reflection that we can obtain from the same object at a range of 10 miles when operating at 3000 mcs. The dimunition of range when operating at 5000 mcs would be about 20%. During cloudbursts there would be an even greater dimunition of range when operating at the higher frequencies.

Back scattering of radar energy by precipitation increases as the frequency is increased. Quantitative results are difficult to obtain but operational results have borne out qualitatively the theoretical considerations of this problem. The Office of Naval Research is sponsoring at Westinghouse Laboratories research which is intended to lead to quantitative information concerning back scattering from rain at microwave frequencies.

Back scattering from the surface of the water also increases as the frequency is increased. In general, reflections from objects masked by scatterers of energy can more easily be distinguished when the resolution of the radar set in both range and azimuth is improved.

Under conditions of anomalous propagation the higher frequencies are somewhat more likely to be affected. If the duct height is small the higher frequencies are more likely to be trapped with a consequent increase of range. To take full advantage of these surface ducts it is desirable to mount the antenna at a height of 50-75 feet above the water line. Under substandard conditions, however, such an antenna height is a disadvantage since the maximum range will be decreased to a greater extent than in the case of a normal antenna height. When the duct is high or the substandard condition extends well above the surface of the water there will be no significant difference between the performance of the different frequencies for a given antenna height.

The development of components during the last few years has been rather intensive and at present the equipment problem is not greatly different for the different frequencies in question. The 3000 mcs equipment has been in service longer and still is considered more rugged and reliable by some engineers in radar work. The wave guide sizes are larger and the attenuation in the guide is somewhat lower. Wave guide fittings, TR tubes, and ATR's can be made to lower tolerances for 3000 mcs so manufacture should be somewhat cheaper.

Improved methods for production of magnetrons has made it possible to closely control the frequency at which they operate. This fact, in conjunction with the broadbanding of many of the RF components has made it possible to greatly decrease the number of tuning adjustments necessary to operate a radar system at top efficiency.

As we move to higher frequencies even though the transmitting magnetron and local beating oscillator percentage frequency stability may remain unchanged, the actual frequency deviation in cycles

per second will increase thereby putting more severe demands upon the receiver AFC system. Along this line it has been possible in the laboratory to keep two 9000 mcs klystrons operating sufficiently closely together in frequency to maintain an audio beat note in a receiver. Naturally any improvements made in equipment for use at the higher frequencies can also be made in equipment for use at 3000 mcs so that any advantages it now holds, such as a smaller wave guide attenuation, a slightly lower receiver noise figure, and perhaps a greater ruggedness, it will no doubt continue to hold.

In the case of navigational radars, these considerations do not seem to be the most important ones, but perhaps they should be kept in mind.

The higher frequencies definitely have the advantage when the problem of bearing resolution vs. antenna size is considered. At 9000 mcs a given beam width may be obtained with an antenna having only one-third the dimensions of a 3000 mcs antenna giving the same resolution, or conversely with the same size antenna operation at 9000 mcs will permit a beam one-third as wide as can be obtained at 3000 mcs.

In "The Advisory Minimum Specifications" issued by the United States Coast Guard, the beam widths recommended for 9000 mcs are 2° in the horizontal plane and 15° in the vertical plane. Assuming an antenna area efficiency of 60% the antenna required would be approximately 36 inches across and 5 inches high. For 3000 mcs the recommended beam widths are 4° in the horizontal plane and 15° in the vertical plane. This would call for an antenna approximately 60 inches across and 15 inches high. The beam width in the vertical plane can be reduced to 4° or 5° if desired, but in this case the antenna must be stabilized. At the present state of the art it is probably more economical to use higher power to offset the effect of the lower gain achieved when using a wide vertical beam.

When making a choice of frequency under the conflicting requirements of light weight, high definition, ease of upkeep, and dependability it should be kept in mind that propagation conditions as well as the bearing resolution offered by a given size of antenna are fixed when the frequency is chosen and that future progress will make no change in these factors.

The decision must be made then between three desired qualities: (1) propagation unaffected by precipitation, (2) high angular resolution to permit navigation in restricted waters, and (3) an antenna of reasonable size. The ultimate outcome will no doubt be decided taking into consideration the area in which a ship

operates; for example: is it more desirable to have consistent long-range operation on the open sea under all weather conditions; or is it more important that the ship be able to negotiate a narrow channel in all states of visibility, although under some conditions the maximum range of the radar will be on the order of a mile or two? Only after all these questions are answered can the best choice of frequency be made.

Information regarding attenuation of energy by precipitation and fog was taken from OSRD Report WPG-11 of May 1945.

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INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN. · · · APRIL 28 - MAY 9, 1947

U. S. ANTI-COLLISION AND NAVIGATIONAL RADARS

- By -

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COMMANDING OFFICER, COAST GUARD CUTTER CAMPBELL

ABSTRACT

This paper presents an outline of the action taken to produce a set of marine Radar specifications which are now in use in the United States. It further presents a review of the commercial Radar equipment which will be demonstrated during the IMMRAN meeting with comments regarding the general use of a shipboard Radar.

U. S. ANTI-COLLISION AND NAVIGATIONAL RADARS

1. From the inception of the art of object detection by the use of electronic devices, the Government, manufacturers of Radar and shipping interests of the United States have been aware of its potentialities as an adjunct to navigation. The ability to detect objects during periods of low visibility has such obvious advantages that it is unnecessary to discuss them here. Suffice it to say that continuous coordinated efforts have been made by all to adapt the war-born electronic devices to the requirements of peace. It was apparent from the first that Radar equipments could be utilized by merchant vessels to assist them in navigating the vessel, particularly in piloting, as an added safety device to prevent collisions, and as a means of materially decreasing average transit time between ports.

2. In the United States the Coast Guard has been delegated the responsibility for disseminating pertinent data on Radar to interested parties and for coordinating, in an advisory capacity, the development activities of those concerned. Early in the post-war period consultations were held between manufacturers, potential users and interested government agencies to determine the most suitable characteristics as applied to the science of navigation. In this connection, considerable research and experimental work was done with 3CM and 10CM band Radars installed on vessels of the International Ice Patrol and on vessels operating along the coastal and inland waters of the United States. The data thus obtained was carefully analyzed, together with that obtained from such sources as the Navy Bureau of Ships, Naval Research Laboratories, Massachusetts Institute of Technology and electronic equipment manufacturers, and incorporated into a "Tentative Advisory Minimum Specification for Merchant Marine Radar." This Preliminary Specification was presented to a gathering of approximately 300 representatives of various interested groups. As a result of their criticisms and suggestions the Specifications were revised. As the art of Radar detection progressed continued revisions to the specifications were issued, the latest revision being that issued on 1 August, 1946. These have been widely published and the details are contained in the document "Electronic Navigational Aids", which has been made a part of the records of this meeting.

3. The Advisory Minimum Specifications have been used by manufacturers and potential purchasers of Radar on a purely voluntary basis. The specifications have served, mainly, to reflect the operational and technical experience and knowledge of the Coast Guard and other government agencies and to make that experience available to commercial interests. Nothing in the specifications

is considered to be a limitation on the development or use of improvements, innovations or the application of Radar for any specified purpose. Their general adoption has been most gratifying. It will be seen that manufacturers have adhered rather closely to the letter as well as the spirit of the specifications and, in many ways, have exceeded their requirements.

4. The development of commercial models of Radar has had three objectives. First, that the equipment reflect and incorporate all new applicable advancements in the field of electronics engineering. Second, that the equipment be capable of operation and interpretation by personnel with little or no training in its use. Third, that the equipment be as economical as possible in original cost, installation, and maintenance. These three objectives are very closely related and, by their nature and precedence of importance, require compromise. For example, the ideal Radar installation might include the use of a large scope, an antenna mounted high and in the clear, a very narrow beam width and a high peak power. These requirements would obviously clash with the cost and installation problem, so compromise has been necessary. It is believed that United States industry has arrived at a suitable practicable balance among the requirements and has produced Radar equipments which are comparatively economical, easy to operate, and still embody the most advanced technical features and operational characteristics available at the present date.

5. The installation problem alone has been one of considerable magnitude, involving: the use to which the vessel is put, whether at sea or in restricted waters; the space available for installation, small or large vessel, including location of antenna and possibly the RF components; and the available power.

6. Perhaps the best method of showing how the various manufacturers have met the problems and objectives involved is to compare some of the salient features of five of the presently manufactured Radar equipments.

a. Three of these sets consist of 3 package units. Two are essentially 2-package units.

b. Three operate in the 3CM band and two operate in the 10 CM band. Some manufacturers are considering both bands and also another band at 5 CM.

c. All use PPI presentation on either a 7" or 12" scope.

d. Pulse repetition rates vary considerably; four sets use the following rates: 800, 1000, 1100, and 2000 pulses per second, while the fifth uses 750 on long range scales and 3000 on short ranges.

e. Pulse lengths vary from 1/4 micro-second to 1/2 micro-second.

f. Peak powers are 7, 15, 15, 30 and 35 KW.

g. Antenna horizontal beam widths are 3.5° and 5° for 10 CM sets and 1.6°, 2° and 2° for the 3CM sets.

h. Antenna rotation speeds are 7, 10, 11, 12, 14 R.P.M.

i. Range scales vary considerably from 1.5 miles to 50 miles; for example, two sets use the following ranges: 1.5, 5, 15, and 50 miles. Another set uses 2, 6 and 30 miles.

j. Radars are available for both A.C. and D.C. powered ships, the required power drain varying from 600 to 1400 watts on A.C. equipped vessels. For operation on D.C. equipped vessels a motor generator is used.

k. Additional repeaters can be used on some sets.

7. The individual manufacturer's specifications will show how these factors have been linked together to obtain optimum performance.

8. It will be seen from this basic comparison of the present models of Radar which are available in the United States that the Advisory Minimum Specifications have been followed closely. In addition to the characteristics just outlined, manufacturers have included many ingenious and useful innovations and accessories to their equipments. As it now stands, Radars are available for almost all types of installation and for a large number of specific and general applications. The performance characteristics of these Radars are so uniformly good that selection of an equipment for a vessel becomes almost a matter of preference for appearance, or of fitting the equipment to a specific vessel which has certain structural and electrical power limitations. It is possible to select Radars which are suitable for installations varying from the largest, fastest ocean liner to a small vessel operating in the restricted confines of the inland waterways and rivers.

9. The matter of price is, of course, important. During the IMRAMN conference in London this matter received considerable attention. It appears now that the matter of price was not as important, as far as the development and use of commercial Radar is concerned, as it then appeared to be. The past few months have shown that United States shipping interests are keenly aware of the advantages -- one might even say the necessity -- of Radar on commercial vessels. These interests have shown that they are not willing to sacrifice a great deal of performance in order to reduce the initial cost of equipment. They realize that a Radar equipment may pay for itself in a short period of time by reducing transit time and by contributing materially to the safety and welfare of the vessel on which it is installed. They further realize that reliability is an absolute necessity and refuse to allow reliability to be compromised by questionable quality. One place where price differentials occur is in the accessories attached to the equipment or embodied in its construction. Each set has its function and performs that function very well. Here, again, the matter of selection almost resolves itself into the taste of the purchaser or the adaptability to his vessel.

10. United States industry with the advice and assistance of the Government is actively engaged in research and further development of commercial types of Radars. It is expected that the next few years will see many improvements over existing types of Radar and that the use of Radar aboard merchant vessels will become so widely accepted that its absence from a vessel of tomorrow will cause as much comment as its presence did yesterday.

11. The usefulness of Radar for navigation may be improved somewhat by the development of Radar aids for more positive identification of certain landmarks. At present the relative position of one target to another is an excellent means of identifying more prominent targets. This system can well be used on an approach to a harbor like New York, but when approaching harbor entrances on long, low, flat beaches it can readily be seen how some difficulty can exist due to there being no distinct target until the vessel gets well within soundings. Here the coordinated use of Radar with other navigational instruments, namely, the Radio Direction Finder (for bearing) and the Fathometer (to check sounding), increases the safety of the vessel and adds to the confidence of the position obtained by Radar.

12. Radar performs its primary function in periods of low visibility. Use of Radar during good visibility increases a ship's officer's efficiency in its use during poor visibility. This applies particularly in entering and leaving port. By constant comparison of Radar scope, chart, and visible observations of surrounding objects the officer not only becomes proficient in the use of his equipment but gains confidence in his ability to interpret scope presentations when it is impossible to visibly detect the surrounding objects.

13. As an instrument for running in periods of low visibility Radar has no equal. This is borne out by comments made by masters of Radar-equipped vessels. On a recent trip made by the CAMPBELL from Boston to New York, in what might be called pea soup fog, traffic was easily detected and avoided long before we came within whistle sound. Incidentally, I was never in doubt as to the vessel's position, as buoys were picked up by Radar at ranges of eight to ten thousand yards. Land was detected long before at ranges of from 15 miles up.

14. In conclusion I would like to leave you with this thought:

> "Careless confidence in the use of Radar can bring about disaster to a vessel - added vigilance and proper use of Radar is an insurance to the saving of lives, property, and time."

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INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN. · · · APRIL 28-MAY 9, 1947

UTILIZATION OF RADAR BEACONS AND REFLECTORS

- By -

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ABSTRACT

In this paper the corner reflector, the Ramark and the responder beacon are discussed with regard to their construction, application and limitations. It is noted that the mariner finds it practicable to safely navigate in most cases with his radar and the usual less glamorous navigational tools without special radar aids. Slides will be used to illustrate certain portions of the written material.

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UTILIZATION OF RADAR BEACONS AND REFLECTORS

Introduction

1. In London one year ago, we examined what was then believed to be the requirements for radar aids. There was general agreement that radar aids would be required in certain cases however there was no agreement as to the exact form such aids would take, either for the active or the passive types.

2. The form which the final commercial radar will take as regards frequency, definition, and peak power has not been sufficiently standardized to permit a complete and accurate evaluation of the radar aids required for all-weather navigation of the various types of harbors, entrances, and coastlines encountered throughout the world.

3. The need for radar beacons and reflectors is dependent upon many factors such as definition and power of the radar, land configurations, availability of radar charts, type and location of buoys, and the skill of the mariner in the application and interpretation of his radar scope picture. In general the higher the definition of the radar the more the picture portrayed on the radar scope resembles the original land and seascape and the less the need for radar aids. Likewise the power of the radar may be sufficient to detect poor targets at distances satisfactory for navigational purposes. A requirement for radar aids exists in those cases where there are land configurations that make poor radar targets or else are not readily distinguishable from other land echoes or targets. Inland waterways which are traversed by bridges and locks present a special problem. The radar detects the bridge but it is not possible to accurately determine by radar means the relative position of the navigable channel with respect to the bridge. The same situation prevails with regard to lock entrances. It was found during World War II that specially prepared radar charts made safe navigation through torturous channels under blackout conditions practicable. This was done with radars considerably poorer in definition than those now available to the mariner and to be demonstrated during this meeting. With regard to buoys, it has been found that large metal buoys present good radar targets, particularly for the 3 cm radars and that normally no additional marking is needed. Furthermore the arrangement of buoys can greatly facilitate identification, for example; when channels are marked by buoys which are directly opposite each other the navigator finds it a very simple matter to properly lay his course There are many cases in which a special pattern of several buoys will serve the same purpose. The subject of the skill of the mariner in using and interpreting his radar scope picture is being discussed elsewhere but suffice it to say that this is something one attains after experience. Many ship's officers are able to do very well witho

any form of radar aids and believe that very few, if any, are necessary. Actually there are many cases in which proper interpretation of the radar data will remove all need for special radar aids.

4. This discussion of radar aids to navigation will consider only three forms of aids, two of which, the Ramark and the Responder Beacon are powered devices while the third, the Corner Reflector, is a passive device. There are other devices now in the laboratory and in the early development stages which offer promise but they are around the proverbial corner or else cannot be adopted because of extremely difficult practical reasons.

Corner Reflectors

5. The Corner Reflector, so named because the early experimental models resembled the inside corner of a box is a very efficient radar target owing to its ability to concentrate incoming energy in a beam back to the radar antenna. Corner reflectors have the advantage of being relatively inexpensive and simple to build, not frequency conscious within wide limits, require no electrical or mechanical power, and last, are relatively easy to maintain. Thus a properly designed corner reflector will provide in concentrated physical size a radar target comparable to a much larger object of random configuration. From this we can see that such reflectors are of little practical value for marking objects which present in themselves a good radar target.

6. There are various possible configurations of corner reflectors which have and can be used. The Coast Guard has found a circular pattern of trihedral corner reflectors satisfactory. In this type of reflector the entering radar waves, upon striking the interior surface of the corner, will be reflected from each of the three planes and return in a direction parallel to and with the same polarization as the incident ray. It can easily be shown that certain other configurations, sometimes used as reflectors do not react in this fashion and are thus unsatisfactory for this purpose. Radar waves entering at oblique angles to the central axis of the corner may be reflected partially or not at all so it is necessary to arrange the corners in a cluster around a circle. This provides very efficient reflections when viewed from all aspects in the horizontal plane. A practical reflector assembly is fabricated of sheet aluminum or steel and may be from 2 to 4 feet in diameter depending upon the lowest frequency of the using radar. No difficulty is forseen in designing a good corner reflector into the basic design of buoy and light structures. A reflector that is a good radar target at the lowest frequency becomes an even better target as the frequency is raised. The corner reflectors to be demonstrated at New London are 31" on a side and appear to be large enough for normal applications for the 3, 5, and 10 centimeter marine radars.

7. The above radar reflectors have been mounted on several sizes of standard U.S. lighted buoys, 8 X 26, 9 X 32, and 9 X 38. With a standard 10 centimeter radar the marked buoy is detected at distances from 2 to 3 times that obtained with a similar unmarked buoy. This is not quite the case when a 3 centimeter radar is used. Here a definite improvement was noted, particularly when the buoy is up-wind during heavy weather, however the degree of change is not as great as with a 10 centimeter radar. The explanation of this phenomenon is that the large steel buoy by itself is a more efficient radar target for 3 centimeter radar than for the longer wavelength, 10 centimeter radar. This points out the fact that reflectors are very useful within their limitations but do not serve to amplify an already adequate radar echo. Mariners on the Great Lakes and along the Coasts of the United States are regularly detecting lighted buoys with radars at ranges of 6 to 7 miles and can and nun buoys at about 4 miles. Normally the navigator does not expect or have any need to know the whereabouts of buoys at distances greater than this. Furthermore, this distance is about the extent of the radar horizon (approximately the line-of-sight-distance) and the addition of reflectors would not increase the range sufficently or be of enough practical value to justify the additional expense involved.

8. At the present time experimental reflectors are installed on buoys in the Ambrose Channel area of New York Harbor, Upper Chesapeake Bay and off New London, Conn. These buoys are installed at strategic locations marking turns and channel entrances. It is noted that these reflectors permit the detection of buoys during periods of heavy sea return during which time an unmarked buoy might not be observed. Experiments are also being conducted with various types of paints and metallic coatings on the reflector and the buoys to determine the effect on the reflecting efficiency of the target for radar detection. The use of radar reflector buoys arranged in the form of a simple pattern has not been exploited to the fullest but it is felt that such an arrangement may be necessary in certain cases involving difficulty of identification. However this could only be justified if very simple and cheap special reflector buoys are designed. Usually the navigator can watch his radar screen and soon determine which targets are stationary and which are moving thus solving the identification problem.

<u>Radar Beacons</u>

9. There are certain cases which may require powered radar beacons for the mariner to make fullest use of his shipboard radar. These cases usually involve identification in regions having many prominent radar targets or where longer ranges are required.

<u>Remarks</u>

10. At the time radar was first released for civil use considerable

thought and investigation was devoted to developing a form of powered radar aid that would require a minimum of maintenance, be relatively inexpensive, could be tended by the regular lighthouse keeper without further training, have low electric power consumption, employ simple, dependable circuits and require a minimum of change and cost to the shipboard radar. Operationally, the beacon should reliably furnish at least sufficient information for the navigator to orient himself and preferably to fix his position. Actually, when the Navigator can definitely orient himself with respect to one radar target he is enabled to properly interpret the radar scope picture and thus proceed with safety. Another factor which received consideration was that all possible efforts should be made to foster and assist in the early development and adoption of high quality radars for the merchant marine.

11. As a practicable solution to this problem the U.S. Coast Guard has several development models of the "RAMARK" or radar marker beacon which gives bearing information only. Two Ramarks are required for a fix. This beacon transmits continuously on the beacon frequency, 9310 mc/s for 3 centimeter radar or 3256 mc/s for 10 centimeter radar and does not in any way depend upon the radar's transmission. In fact, a microwave receiver in conjunction with a directional antenna would give good bearings. This eliminates one of the major problems in connection with the responder type beacons, to be described later, while at the same time increasing the usefulness of a simple radar equipment. The radar equipment must be capable of efficiently receiving on the beacon frequency. To use the Ramark, the mariner operates the beacon receiver control which tunes the radar receiver to the beacon frequency and clears the scope of the radar picture — he then observes a pencil of light extending radially from the center to the periphery of the scope on the bearing of the beacon. The accuracy of the bearing and the width of the light beam corresponds to the accuracy and azimuthal resolution of the radar. If the mariner sees the Ramark and his radar is operating properly he can depend upon the bearing. The navigator makes use of this information in a similar manner to bearings on lights, shore objects, etc. Like the corner reflector there is no ready means of identification other than properly locating the beacon. It is not anticipated that this will be a serious problem owing to the short ranges involved and the small number of beacons required in any one area. Other means of coding the beacon are now under study with the hope that this feature can be added with a minimum change to the ship's radar. Ramarks have an advantage, not enjoyed to the same degree by other radar aids, of giving bearing information under all but the most severe weather conditions. One Ramark, with any other suitable passive radar target, can be used to provide a range.

12. Physically the Ramark consists of a low power source of radio frequency energy, a 100 kc/s multivibrator and modulator circuit for keying the radio frequency source, a resonant cavity for checking the frequency and output, a simple antenna and a power supply. Peak output powers of the order of magnitude of one hundred milliwatts to a few watts should be ample for most applications. This amount of power is condiderably in excess of that returned as an echo from normal radar targets. High power for marine use is not necessary and in fact may be a detriment in most situations. The equipment would normally be contained in one cabinet. It is envisaged that a Ramark could be installed and maintained with little difficulty at an existing light or other aid to Navigation Station. The equipment installation would be in duplicate for each frequency in order that operation could be switched to the standby beacon in case of failure of the beacon in use. It is entirely feasible to perform this transfer automatically as well as providing automatic frequency stabilization of the beacon itself.

Responder Beacons

13. Early in World War II a responder type beacon, known as "RACON" was developed for aircraft as a military necessity. The responder beacon concept is an idealized system which is highly desirable from a purely operational standpoint; however, both the radar and the beacon must be designed as sister components, each dependent upon the other. Generally speaking the circuits are complicated, expensive, difficult to maintain and the ordinary commercial radar can not utilize them without adding to the construction costs. The principle of operation is straight forward, the beacon receives the incoming radar signal, converts it to a coded signal and retransmits to the radar on the beacon frequency. Theoretically the time required to perform this operation is small and fixed in amount, usually 2 or 3 microseconds, so that the error introduced in range is negligible in the case of aircraft but not at all in the case of precision surface piloting. In order to prevent saturation of the beacon it is necessary to require the radar transmitter to transmit within the specified frequency limits with a long or otherwise, modified pulse, when beacon signals are desired. Even with this precaution the beacon may become saturated in congested shipping areas. As in the case of the Ramark the radar receiver must be modified to receive efficiently on the beacon frequency. The responder beacon combines in one operation the determination of the distance and bearing to the beacon thus giving a fix. The presentation on the radar scope consists of a series of dots extending radially to the edge of the screen on the bearing of the beacon. The distance to the beacon is determined by noting the range to the first dot, the remaining dots and spaces serve to identify the particular responder beacon. Military aircraft have found this device very important for

general navigational purposes. There are a number of Racons in operation throughout the United States at the present time for military aircraft. It is believed that future developments and research will eventually provide us with a simplified responder beacon system more nearly meeting the requirements previously set forth in this paper.

Closing

14. Various forms of radar aids to navigation have been examined and it was found that corner reflectors have many advantages to recommend their application for marking certain buoys, low lying land and for other objects not in themselves good radar targets. To overcome the limitations of reflectors it is also in some cases necessary to use powered radar beacons. The Ramark constitutes a practicable solution to the latter problem, requires a minimum of change to the shipboard radar and adequately assists the mariner in orienting himself. If continued use of marine radar indicates the need, we can anticipate a responder type of radar beacon meeting our requirements. We also find that the mariner, and it is desired to specially emphasize this point, can do very well indeed with his radar and the usual less glamorous navigational devices. It is now essential for the maximum utility of radar that some degree of standarization be attained internationally with regard to radar and beacon frequencies and radar aids, particularly beacons.

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INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
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MODERN DEPTH FINDERS

- By -

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ABSTRACT

This paper reviews the art of depth finding beginning with a brief history and ending with a description of several late-model instruments.

The physical principles underlying the operation of modern depth finders are separated, classified, and briefly explained. The manner in which these principles are integrated into complete systems is indicated. Typical examples of depth finder records are included.

MODERN DEPTH FINDERS

Introductory

1. Depth finding on ships at sea is an ancient art. Until very recent times, the lead line, an obvious and simple device, was the tool used for sounding. There is an interesting reference to sounding in the Bible, 27th Chapter of the Acts of the Apostles. It is the story of the shipwreck of Paul.

> "------about midnight the shipmen deemed that they drew near to some country. And sounded, and found twenty fathoms; and when they had gone a little further, they sounded again, and found it fifteen fathoms.
>
> Then fearing lest they should have fallen upon rocks, they cast four anchors out of the stern, and wished for the day."

I have found a reference to 18th century soundings made in 5000 fathoms using a lead of 440 pounds on a 25 mm rope. One and a half hours were required for the weight to reach the bottom. During the 19th century, the Scotch scientist, Lord Kelvin, introduced his "Sounding Machine". He recorded depth by the pressure which water exerted to compress air in a chemically treated or ground glass tube. This method gave either a permanent or temporary depth record depending on the type of tube used. With a recent engine driven sounding machine and a 36 pound lead, about three minutes are required to make a sounding in 300 fathoms.

2. We now have at our command automatic and much more rapid means which make use of the fact that water is a good transmitter of sound. An impulse of sound sent downward from the ship will travel to the bottom, will be reflected there as an echo which will return to the ship after the lapse of a measurable time. The time of arrival of the echo when compared with the time of emission of the impulse gives the time of transit (t). The velocity of sound (c) in water may be considered a constant except for refined measurements. Hence, the depth (d) can at once be found from the equality $d = ct/2$. An average velocity for sound in sea water usually used for setting echo depth finders is 4800 feet per second. This is enormously greater than the speed of any ship. The high velocity is at once a help and a hindrance - a help in that acoustic depth finding is largely independent of ship's speed - a hindrance in that accurate measurement of short time intervals is demanded. It requires modern techniques to measure accurately these small time intervals especially

in shoal water where the time of signal transit is very small. To sum up:

Modern acoustic depth finders:

(1) are independent of ship speeds

(2) can be used effectively in any depth of water

(3) are continuously indicating

(4) provide a permanent record of depths passed over

Brief History of Echo Depth Finders

3. Although the title of this paper was originally "Post War Depth Finders", developments took place prior to and during the War so that the title "Modern Depth Finders" seems more appropriate. The subject cannot be seen in proper perspective without an examination of these developments.

4. The earliest record of the acoustical method I have found is an account published in 1911 of the work of Alexander Behm of Kiel, who used a chronograph to time the echo from an explosive detonated underwater near the surface. Another early form of sound source was a hammer blow on a steel diaphragm set into the hull of the ship. Modern methods might be said to date from the work of Pierre Langevin who first used the piezoelectric effect of quartz crystals to produce an intense high-frequency sound in water and used the principle in 1918 for echo depth finding. The magnetostriction effect was discarded by Langevin but later used by A.B. Wood and others with considerable success.

5. Two methods now in general disuse are the "Sonic" method and the "Angle of Reflection" method. In the Sonic method the Fessenden oscillator was used. This was a powerful electrodynamic "loud speaker" especially constructed to produce an intense underwater sound signal which could be timed in its travel to the bottom and back. The Angle of Reflection method depends upon the measurement in a vertical plane of the angle of reflection from the bottom of sound originating at the ship's propellers or emitted from a Fessenden oscillator mounted in the after part of the hull. Angle measurement of acoustic rays is a special property of the "Acoustic Compensator" which, for operation, depends upon the "Binaural Sense" of the human hearing apparatus. This method was developed for depth finding by Dr. H.C. Hayes of the U.S. Naval Research Laboratory.

Modern Depth Finders

6. Modern depth finders use frequencies of oscillation in the ultrasonic range, which is above the range of hearing. The principal advantages are:

(a) Ship noise and water noise are at a maximum in the audible range and therefore do not interfere.

(b) Sources and receivers of acoustic energy, which in the art are called transducers, can be of practical size and yet send out a beam of sound; a consequence of the fact that the wavelength of sound is short compared with the transducer diameter.

(c) Effective use can be made of the physical phenomena of piezoelectricity and magnetostriction. These two make possible reciprocal conversion of ultrasonic vibration and electromagnetic energy. Once the acoustic energy is converted into electromagnetic energy the enormous versatility of electron tube circuits is at our command.

7. Modern Depth Finders have five elements in common. These will first be enumerated, then described in some detail.

(a) Transducers for reciprocal conversion of acoustic and electromagnetic energy.

(b) Electronic or electrical means for driving the transducer at high vibrational power level.

(c) Electronic means for amplifying the weak echo energy picked up by the transducer.

(d) Means for accurate measurement and continuous indication of depth.

(e) Means for making a permanent record of depths which the ship is passing over.

Transducers

8. Modern transducers without notable exception are of two classes: (1) Piezoelectric and (2) Magnetostrictive

9. Langevin's early piezoelectric transducer was composed of two thick discs of steel with thin quartz crystals cemented between them. A cross-section of the transducer is shown on Plate 1. The "sandwich"

formed a resonant mechanical system which, when excited, vibrated in the direction of its thickness at an ultrasonic frequency of about 40 kilocycles per second. Because of the loading effect of the steel plates 2500 alternating volts across the crystals produced a good amplitude of vibration which without the load required 50,000 volts - an impractical figure. In use, one of the steel plates is in contact with the water.

10. Rochelle salt crystals are highly active piezoelectrically but have had restricted use in transducers for echo sounding because of their sensitivity to temperature changes, low temperature of crystalline breakdown and general fragility. Other synthetic crystals are more stable, if less active, and are now in use in transducers, some with and some without resonators.

11. Some echo sounders use two transducers, one for transmitting, one for receiving; others use but one. Two transducers are used in shallow water depth finders employing damped pulse transmission.

Magnetostriction

12. Some of the ferromagnetic metals, especially nickel, exhibit the property of magnetostriction, which in nickel is a minute shrinkage in dimension parallel to the direction of a superimposed magnetic field. Conversely, mechanically induced changes in dimension will change the magnetization of nickel. These two reciprocal effects make nickel a usefully active transducer material for the reciprocal conversion of acoustic and electromagnetic energy.

13. Magnetostrictive transducers have evolved in several forms: (a) laminated stacks, (b) laminated toroids, (c) nickel tubes attached to resonating plates.

14. Laminae punched from thin nickel sheets are stacked one on top of the other and cemented together in such a way as to make a compact block of the approximately rectangular form shown on Plate 2. Alternating current passing through the coil causes synchronous vibration of the stack in the direction of the magnetic field. Sound radiation takes place from the upper and lower surfaces of the stack; that is, from the edges of the nickel sheets. The laminated structure familiar to all electrical engineers, reduces parasitic eddy currents and permits deep penetration of the magnetic field into the stack. Stacks have been made in a number of forms and are generally assembled into larger blocks having radiating areas large with respect to the wavelength of the radiated acoustic energy. The result is a radiator capable of emitting a beam of sound.

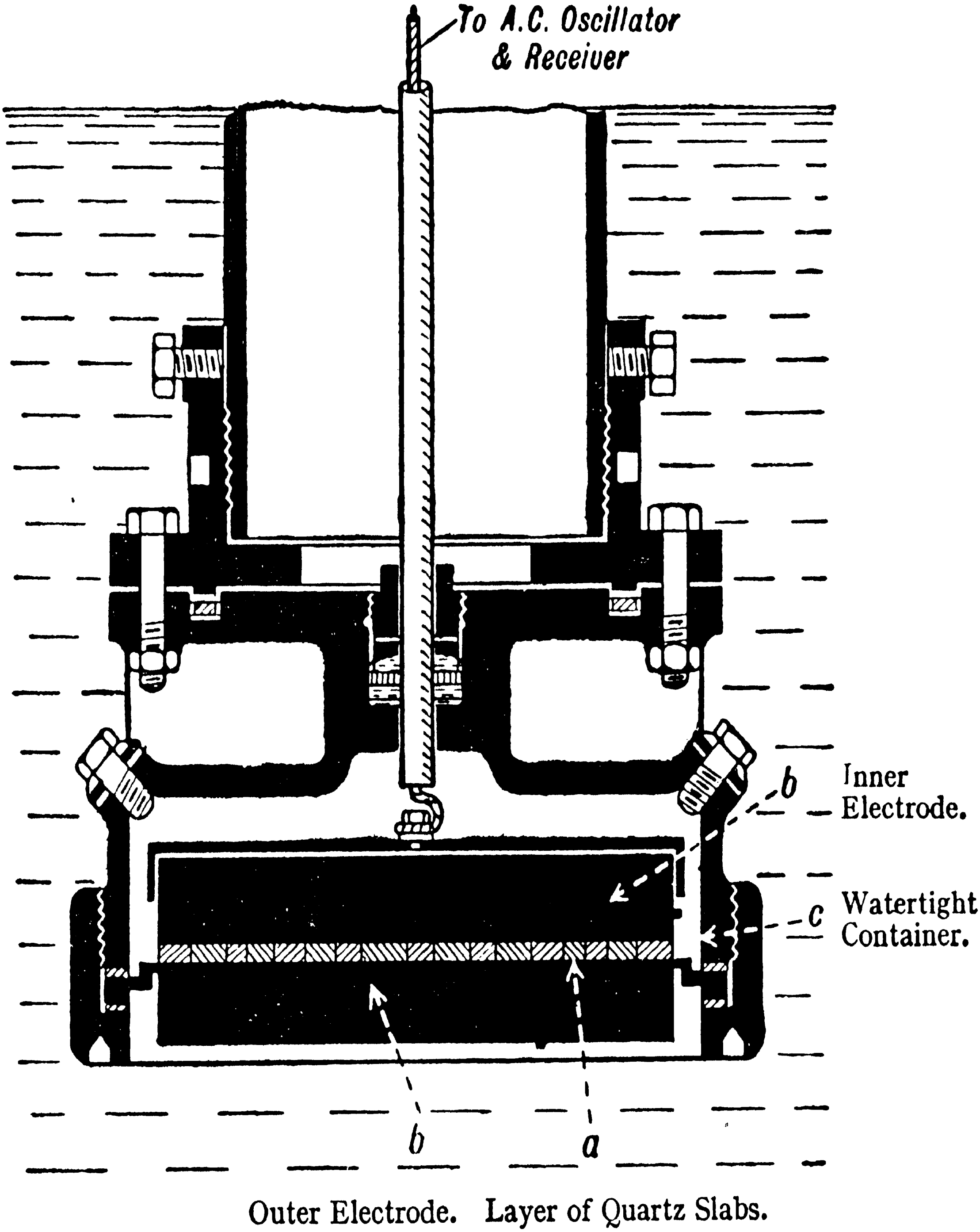


FIG. 48—Langevin Quartz Supersonic Transmitter

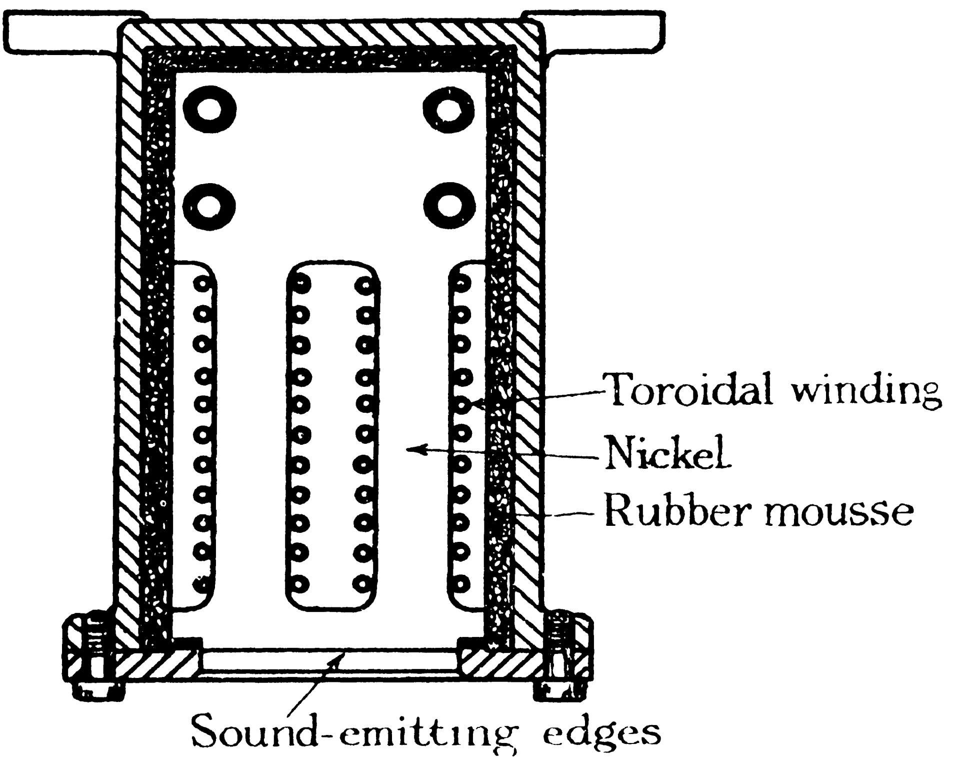


Fig. 5.—Section through strip oscillator.

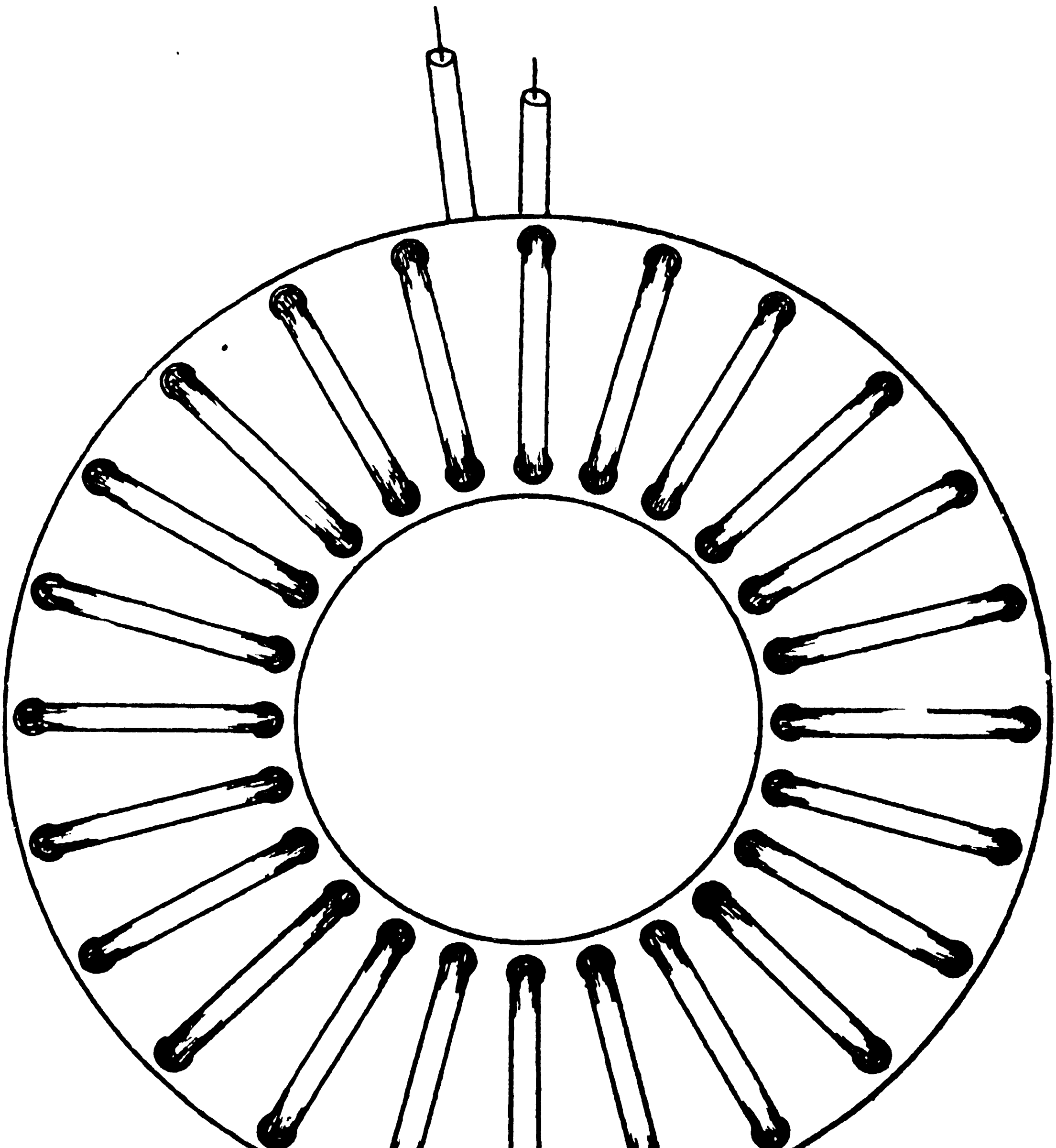


FIG. 4.—Ring-type oscillator.

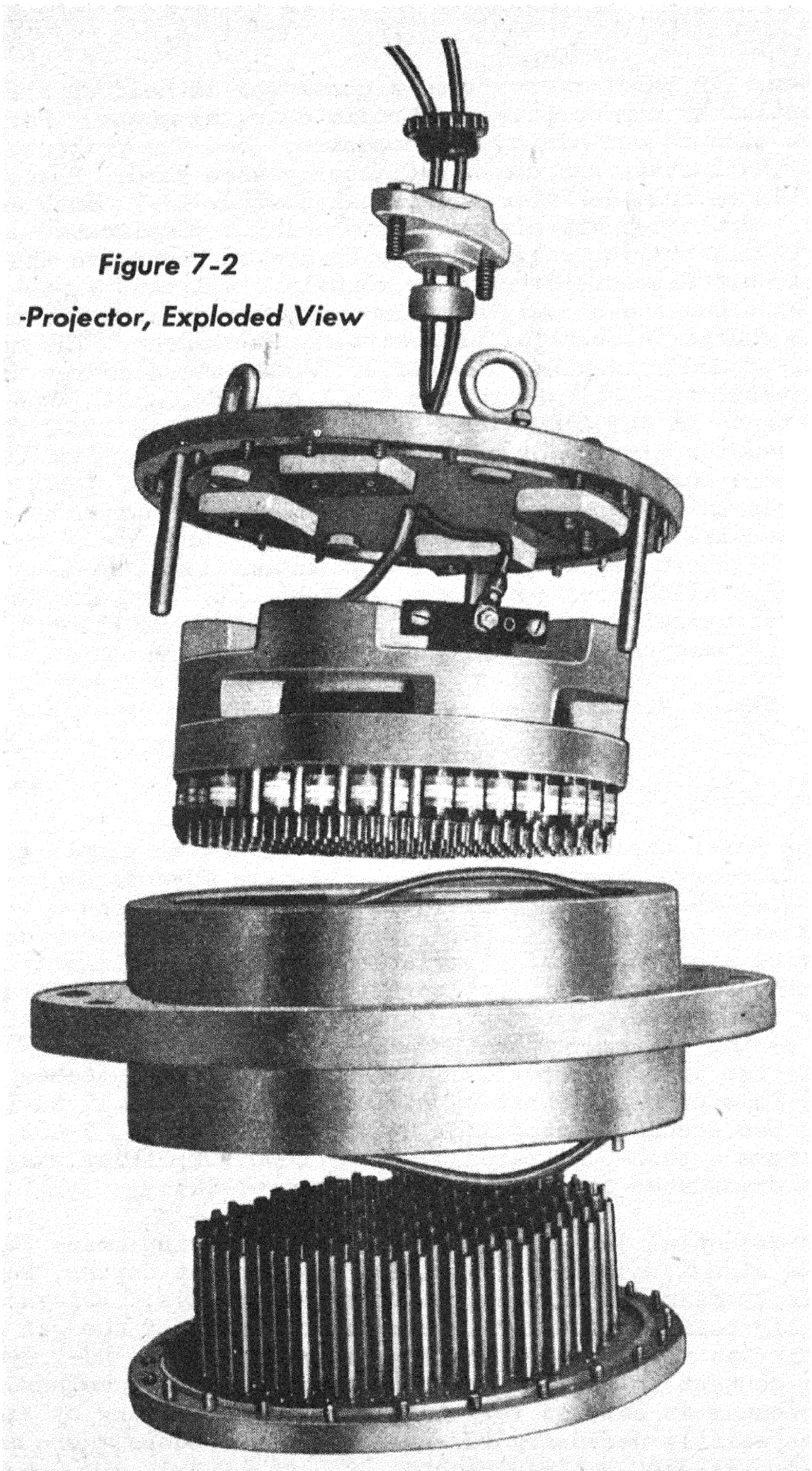


Figure 7-2
-Projector, Exploded View

784078 O—48——15

c.w. system. In the former system a condenser is held at a rather high potential by appropriate electronic charging means. Periodically the series circuit containing the condenser and the projector is closed at the instant the depth indicator passes zero. Plate 5 is the circuit diagram for the Submarine Signal Company NJ-7 Sonar Sounding Equipment. Apologies are offered for showing a complicated diagram in a short talk but it seems to me to be unwise to remove the illustrative circuit elements from their context. All that I wish to do here is point out the circuit details having to do with the surge of electrical charge through the transmitting transducer. The method is typical of modern keying. Rectifier V-402 puts a charge upon the storage capacitor C-404. Rectifier V-401 charges C-401. When the keying contacts in the indicator close, the charge on C-401 flows off to ground causing a surge of current through the primary of transformer T-402. The induced voltage in the secondary of T-402 ionizes the argon gas in the discharge tube V-403 making it conductive. This operation permits the charge on C-404 to surge through the transmitting projector. A short damped pulse of high intensity ultra-sound of frequency 21.6 kilocycles per second is sent out. The impedance of the projector circuit is usually adjusted so that the electrical resonance frequency coincides with the mechanical resonance frequency of the projector. The condenser discharge method is generally used in shallow depths and has been incorporated in many practical instruments.

Power Amplifiers

22. The power amplifier type of driver is not as simple as the condenser discharge type but has about the same advantages over the latter as inspired the change of radio operation from spark to continuous wave transmitters. C.W. permits close frequency control by the use of a stable, easily variable, low power oscillator and permits ready adjustment of the length of outgoing signal. This system is usually used where great depths are to be sounded. Plate 6 is the schematic wiring diagram of the NMC-1 depth finder which uses the power amplifier type of driver. The master oscillator (tubes V-401 and V-402) is a push-pull Hartley circuit tunable from 17 to 19 kilocycles per second by capacitor C-405. Tubes V-403, V-402, V-405, and V-406 form a push-pull parallel plate power amplifier stage which drives the transducer through the transformer T-403.

23. An essential part of the driver is the keying means for turning the signal on and off. In medium and great depths, keying is possible by means of simple contactors and relays. Relays are now generally being superseded by one or the other of the gas discharge tubes. This was noted before in the discussion of the NJ-7 equipment. The timing contact in the indicator however is usually mechanically operated because it carries very little current. Keying by electronic means is especially necessary in shallow depth finders where many short pulses are sent out per second.

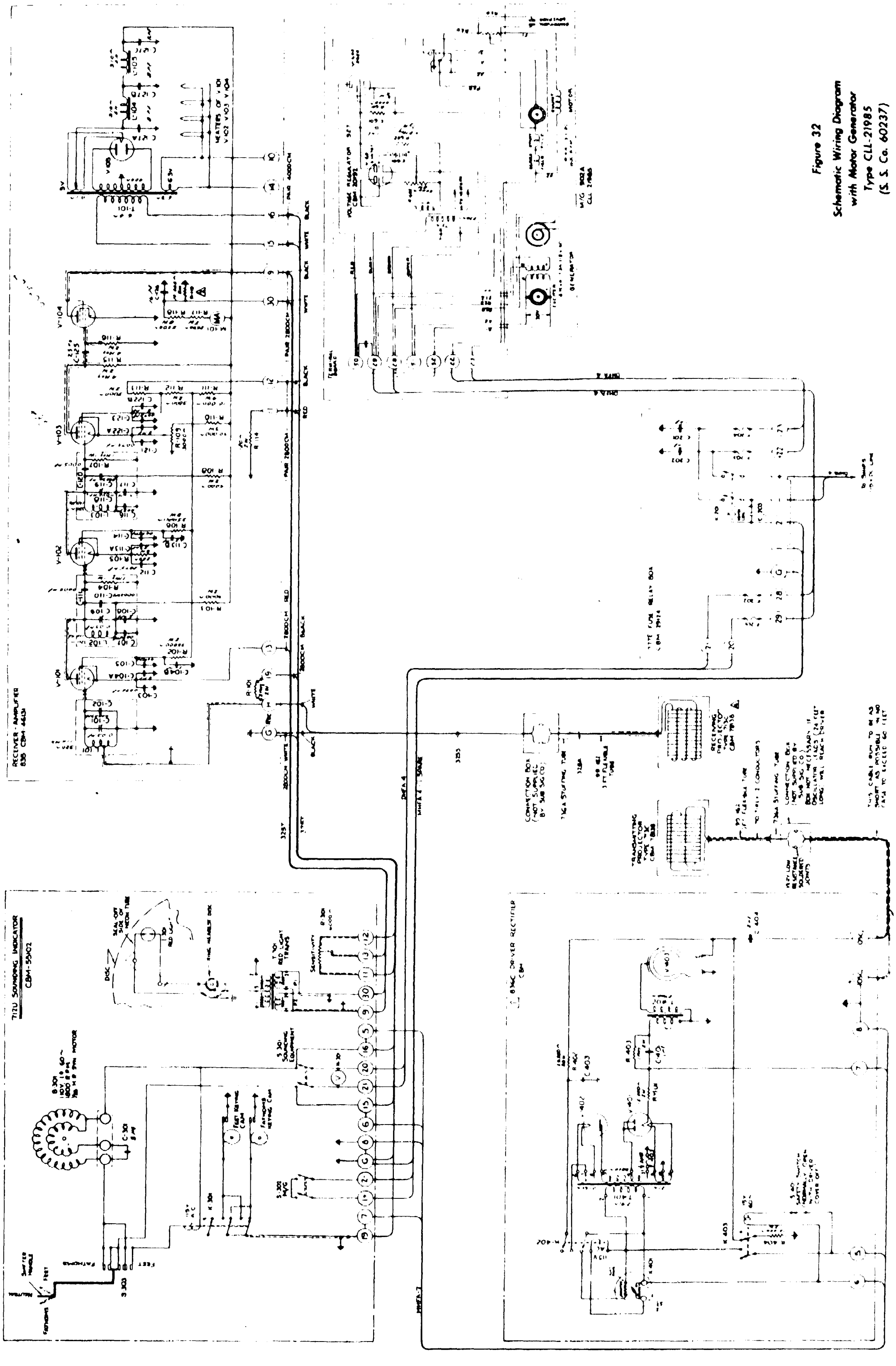


Figure 32
Schematic Wiring Diagram
with Motor Generator
Type CLL-21985
(S. S. Co. 60237)

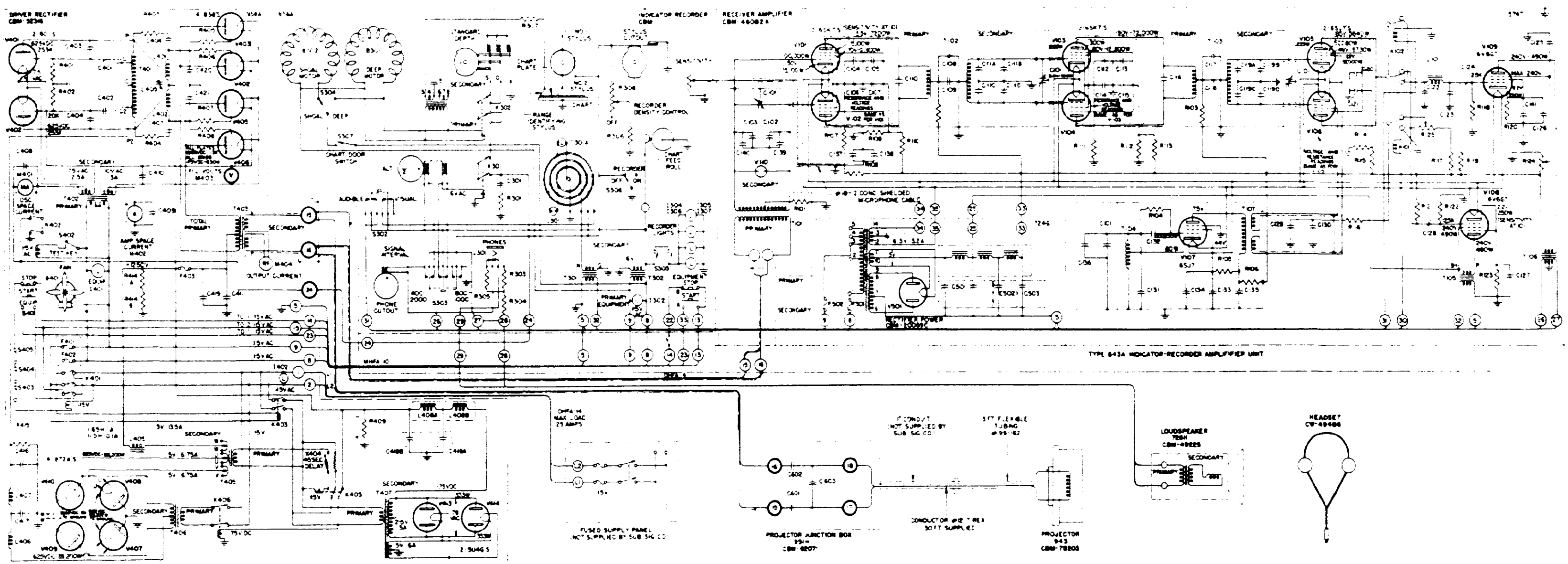


Fig. 7-30
Schematic Wiring Diagram with Voltages.

Receiver Amplifier

24. The direct observation of the echo by means of telephone receivers connected to a carbon granule microphone has long been replaced by electron tube amplifiers. These have taken many forms. In general, the amplifiers are conventional, with several stages tuned to the mechanical resonance frequency of the receiving transducer. The amplified ultrasonic signal is mixed with the output of a local oscillator and is rectified for an audible indication of the echo if desired, or the ultrasonic signal is rectified and the resulting pulse raised in voltage to flash the neon indicator or operate the recorder.

25. The essential function of the electronic receiver is to take the minute electrical potential developed in the receiving transducer by the echo and amplify it so as to actuate a loud speaker, an indicator or a recorder. Receiver amplifiers have had many variations.

Timing Means and Indicators

26. A stop watch can be used for great depths of 2000 fathoms or more with reasonable accuracy. A constant light rotating uniformly around a circular depth scale can be used, provided an audible indicator of echo reception is used to mark the instant for scale reading. This is little better than the stop watch.

27. The next step forward was the use of a neon lamp flashed by the echo-induced and amplified voltage. Three forms of flashing neon lamp have come to my attention. One form is made to rotate at a constant angular velocity in juxtaposition with a circular fathom scale. The amplified echo-voltage is fed to the neon lamp through appropriate slip rings. When the lamp passes zero fathoms, the outgoing signal flashes it. At the instant of echo reception it is flashed again. Persistence of vision permits considerable precision in reading the scale opposite the flash. In another system, the neon lamp is stationary on the axis of the circular fathom scale and the flash is reflected to the scale by a system of mirrors or prisms fixed to the rotating arm. Still a third system is provided with a full circle neon tube behind the scale. An opaque disc with a narrow radial slit rotates at constant angular velocity between the tube and the scale. The rotating neon lamp seems to have met with most favor and its use is exemplified by the NMC-1 sonar depth indicator shown on Plate 7.

28. From what has been said in connection with indicators, the precision of depth determination clearly depends on the degree to which the angular velocity of the indicator can be maintained constant at known value. Dr. Dorsey of the U.S. Coast and Geodetic Survey used an indicator motor wherein the angular velocity was

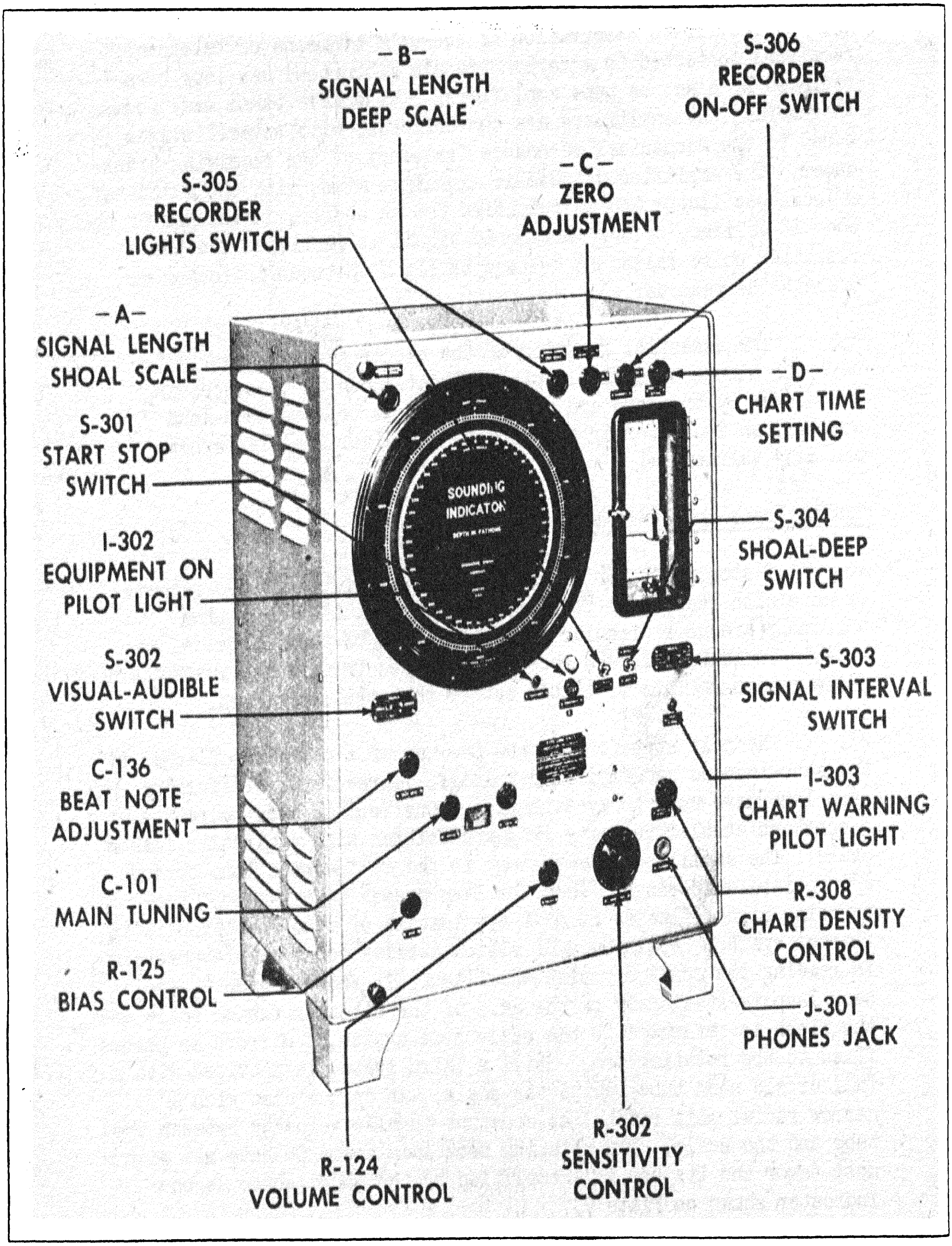


Figure 4-3—Indicator-Recorder-Amplifier Panel Controls

controlled by a tuning fork. This system resulted in the very accurate determination of depths necessary for hydrographic surveys. The English systems described by A.B. Wood used a DC motor with governor. Synchronous AC motors are favored in American systems. Here the constancy of speed depends on the accuracy of alternating power frequency control. The frequency is checked from time to time by vibrating reed frequency indicators. One French system of the S.C.A.M.-Touly type used a spring actuated clock.

29. Two rather special systems devoid of mechanical indicators are exemplified by the Bludworth Marine shallow depth finder and the so-called FM system. The Bludworth Marine scheme indicates depths on a milliammeter with a suitably calibrated scale. Plate 8 is a photograph of the indicating meter which is calibrated in feet.

30. The frequency modulated system (FM) has been suggested by several workers in the field. The earliest record I have found of this system having been used for echo sounding was in a 1938 publication by Matsuo of the Tohoku University of Japan. In this system, the frequency of oscillation of the transmitting transducer was made to vary over the rather wide range of five kilocycles per second at such a rate that the change in frequency was proportional to time. The receiving amplifier was arranged to receive, direct from the driver, a small part of the outgoing signal to which was added the amplified echo signal. Because the two signals varied in frequency at the same time rate, they differed by a constant frequency interval as long as the depth remained constant. The frequency of the beat note obtained by rectification was proportional to the time displacement between the two signals. This time displacement was the time necessary for transmission of sound to the bottom and back. A meter which measured the beat frequency and was calibrated in meters indicated depth with an accuracy of 1% and a range of 75 m. This system gave continuous indications but demanded a wide band transducer operating at high ultrasonic frequencies of about 100 kilocycles per second or more. Because of absorption of acoustic energy at high frequencies, this system has not gained wide spread usage.

Recorders

31. Audible indicators and flashing or moving lights require the concentrated attention of an observer and leave no permanent record. A great advance was made when automatic means were provided for recording on paper the depth under the vessel as a function of time. For a vessel moving at constant speed, the result is an automatic plot of the contour of the sea bottom along the ship's track. The advantages of such a device are numerous. Constant attention of an observer-recorder is not necessary. The permanent record can be returned to home base. The plotted bottom contour can be studied at leisure which is especially important in hydrographic work. For

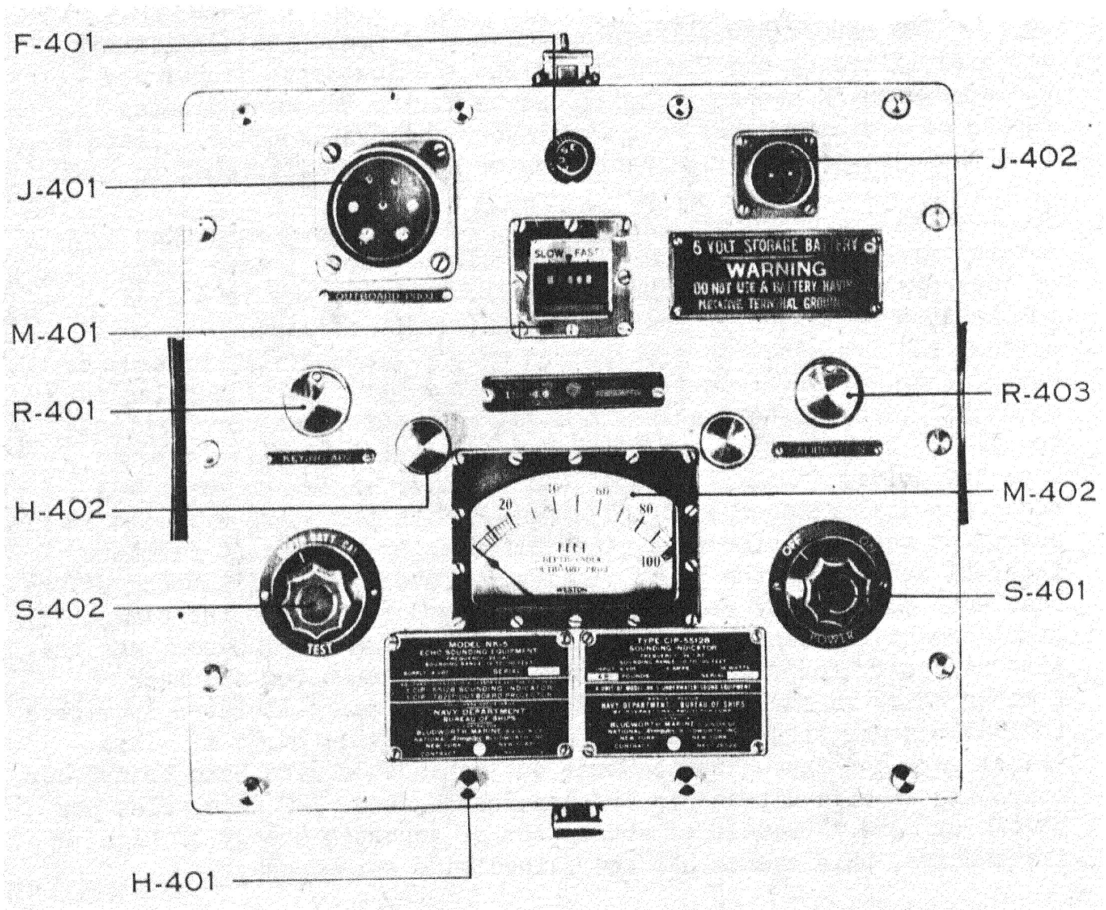


FIGURE 2-1
SOUNDING INDICATOR, TYPE CIP-55128,
COVER REMOVED

position finding at sea, the depth-finder record can be accurately compared, on the chart table, with charted bottom contours.

32. All recorders are the same in principle but differ in detail. The changes have been made in the interest of convenience and accuracy. All consist of a wide strip of paper drawn across a flat platten at constant velocity from a storage roll to a take-up roll. Over the flat area a moving stylus writes the depth record. The stylus may be made to move over an arc of a circle by continuous rotation or by oscillatory repetition. It also may move across the paper by rectilinear oscillation. The output of the echo amplifier is connected to the moving stylus so that a mark is made on the paper at the instant of echo reception. This manner of marking has gone through several evolutionary stages.

33. An early French recorder manufactured by S. Marti used smoked paper on which the stylus scratched a fine line. To mark both the outgoing signal and the echo, the stylus was made to oscillate a few cycles by a delicate electromagnet on the rotating arm. The chart was fixed by a suitable transparent coating. A sample record is shown on Plate 9.

34. A.B. Wood describes a system still in use where the record is made by electrolysis on moist paper treated with potassium iodide. When dry, the record is, if properly stored, permanent. There is some shrinkage but for accurate work corrections can be made. The intensity of the record is roughly proportional to the strength of the echo. Plates 10 and 11 are reproductions of depth finder records made on potassium iodide paper. The first is a reproduction of a record taken in 1932 and reported by Wood, Smith, and McGeachy in the Journal of the Institution of Electrical Engineers for 1935. The second, Plate 11, a reproduction from an account of the search for the Lusitania wreck published in the Hydrographic Review 1936, was made with a British Admiralty supersonic echo sounder. The fine detail speaks well for the perfection of the sounder.

35. The third type of record marking is exemplified by the system used by the Submarine Signal Company. In this system, a black, dry, conducting paper is coated on its active face with a white wax. The feet-fathom lines are printed on the paper. The amplified echo potential causes a spark to jump from the stylus to the paper, thus burning away a minute spot of the white coating at each peak of the ultrasonic oscillation permitting the dark background to show through. The blackness of the record, although not strictly proportional to the strength of the echo is close enough to give character to the record. The nature of the bottom is indicated as to whether it is rock or mud; thermal and saline stratification are indicated; schools of fish may be detected. Plate 12 is an example of a dry-paper spark

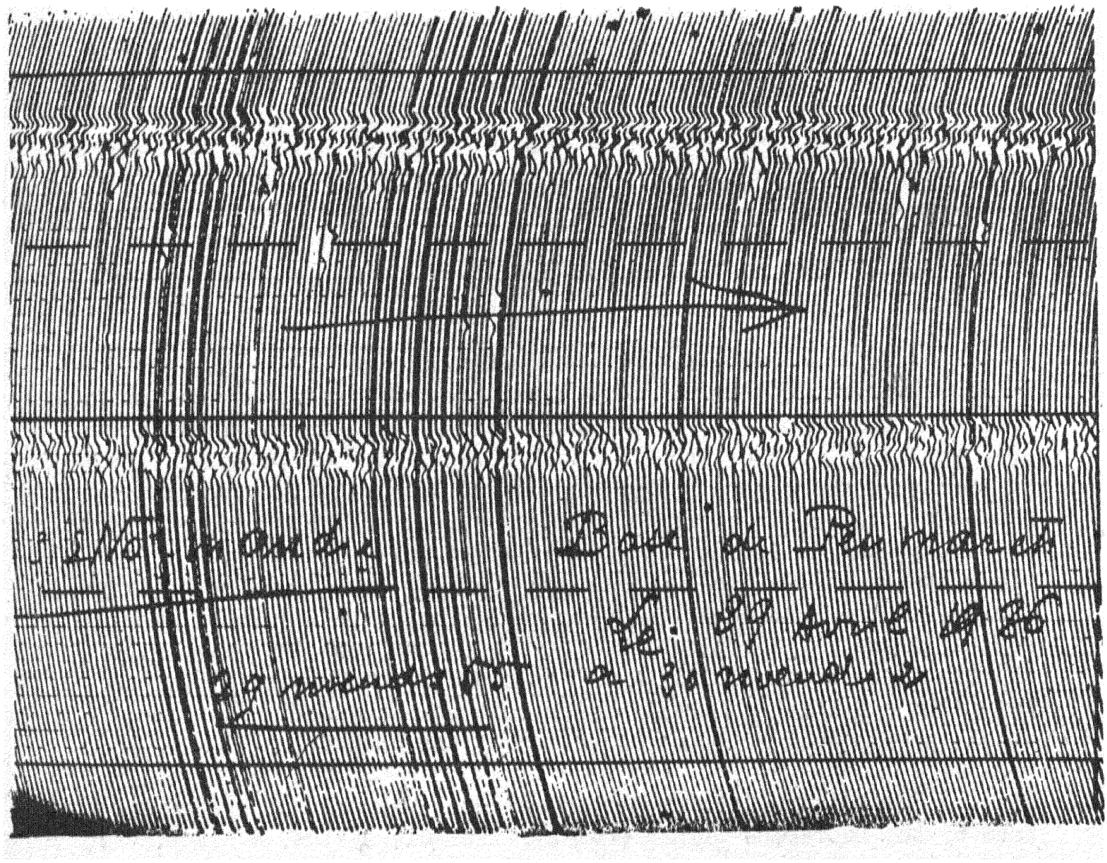


FIG. 1

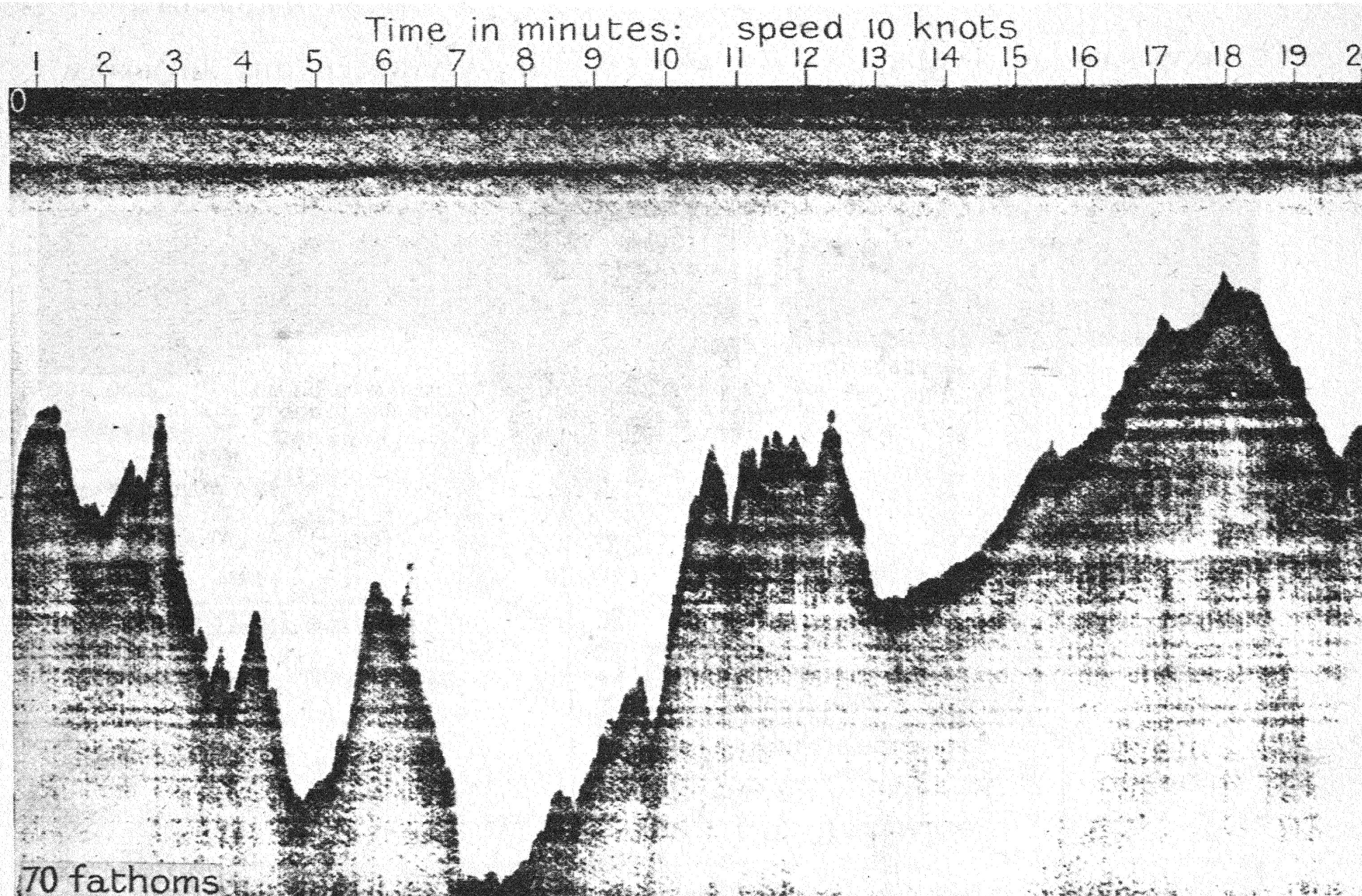
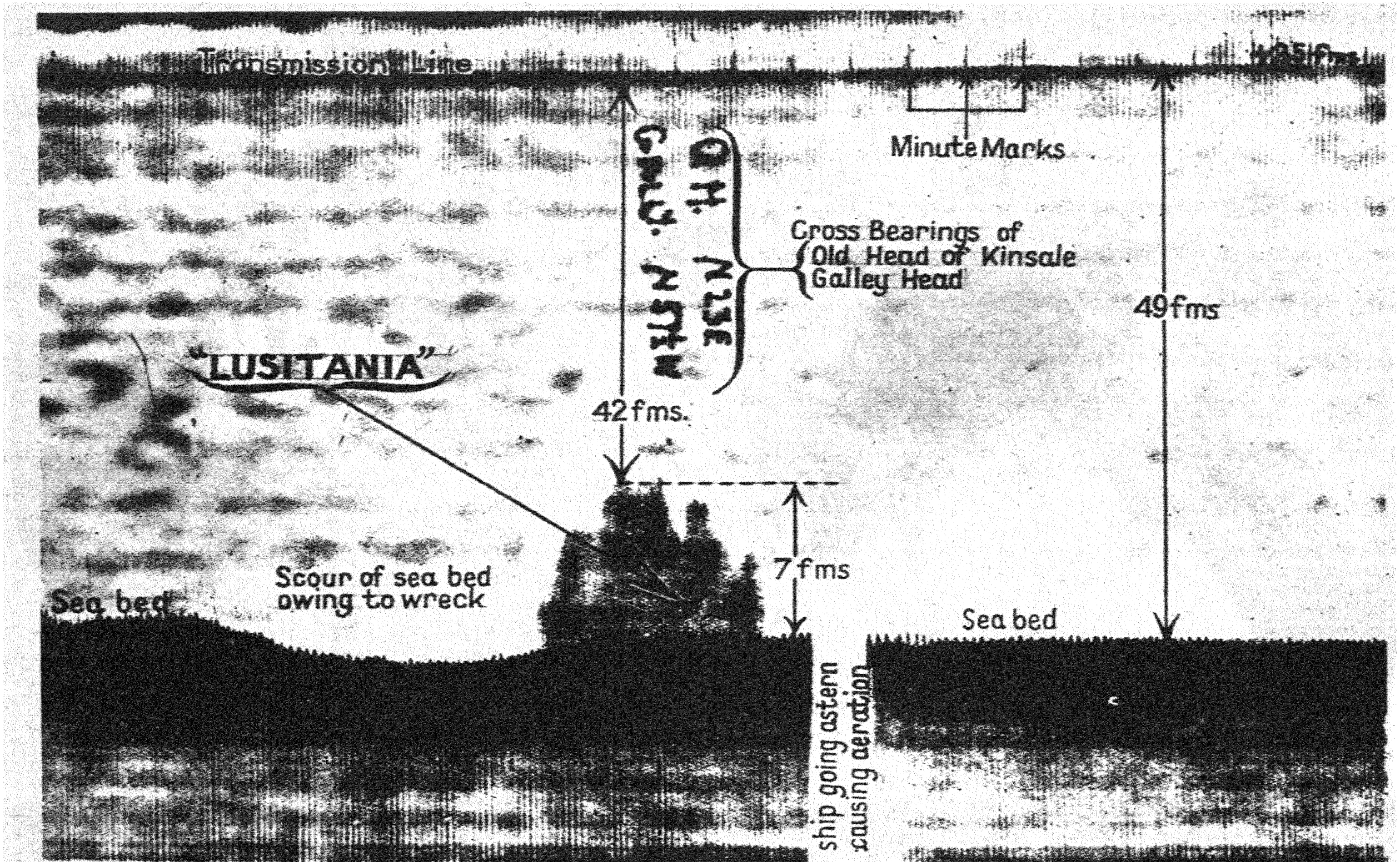


FIG. 23.—Record made by Grimsby trawler " Glen Kidston " near Bergen. Damped-impulse transmission.

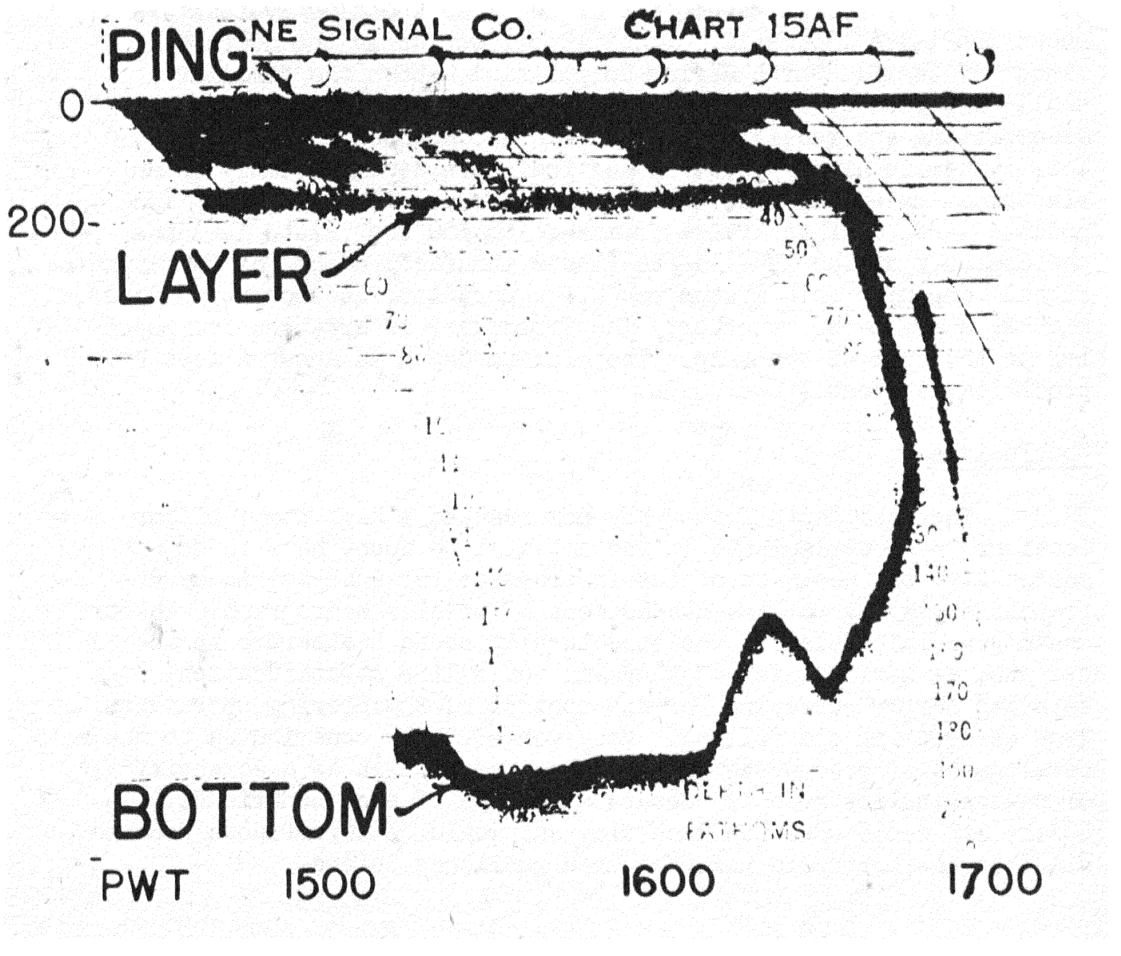


WRECK OF THE "LUSITANIA"

ECHO SOUNDING RECORD

ÉPAVE DU "LUSITANIA"

ENREGISTREMENT OBTENU AVEC L'ÉCHO-SONDEUR.



8 JUNE 1945

JASPER PROCEEDING SOUTH AND ENDING AT NORTH END OF SAN CLEMENTE ISLAND

discharge record. This is a reproduction of a sound chart made by the University of California Division of War Research during a study of sound scatterers in the Pacific Ocean and is not intended to be an example of the very best that the system can do in the presentation of detail. The chart shows a layer of reflecting material which was identified as schools of fish.

36. The pictorial assemblies of two echo sounding systems are shown on Plates 13 and 14. Plate 13, illustrating the depth finder of the Bludworth Marine Corporation, shows the familiar small-boat form of over-the-side transducer arrangement. The transmitting and receiving transducers are mounted in the "fish". This system is highly portable and indicates depth directly on an electrical meter but does not have a recorder. The precision is about ± 1 ft. over the range from zero to 100 ft. Plate 14 shows the assembly of the NMC-1 depth finder manufactured by the Submarine Signal Company. This system has c.w. operation, uses one transducer, and has a dry paper recorder. The transducer is arranged for mounting in the hull of the ship. The minimum depth is about 4 feet and precision is about ± 2 or 3 ft.

Conclusions

37. The echo depth finder has now reached a high state of perfection. New developments in the art will no doubt have to do mostly with the use made of the instrument; for example; in hydrographic surveying for the development of precise hydrographic charts; oceanographic studies of the structure of sound scatterers in the sea such as marine life and thermal, and saline stratification; detailed harbor surveying for the control of engineering operations such as dredging and filling. Many workers have contributed to the development of echo depth finders and have used it as a scientific or navigating instrument. Separate mention of each contributor to the art would take too much time and would be superfluous because all that has been said here has been published before.

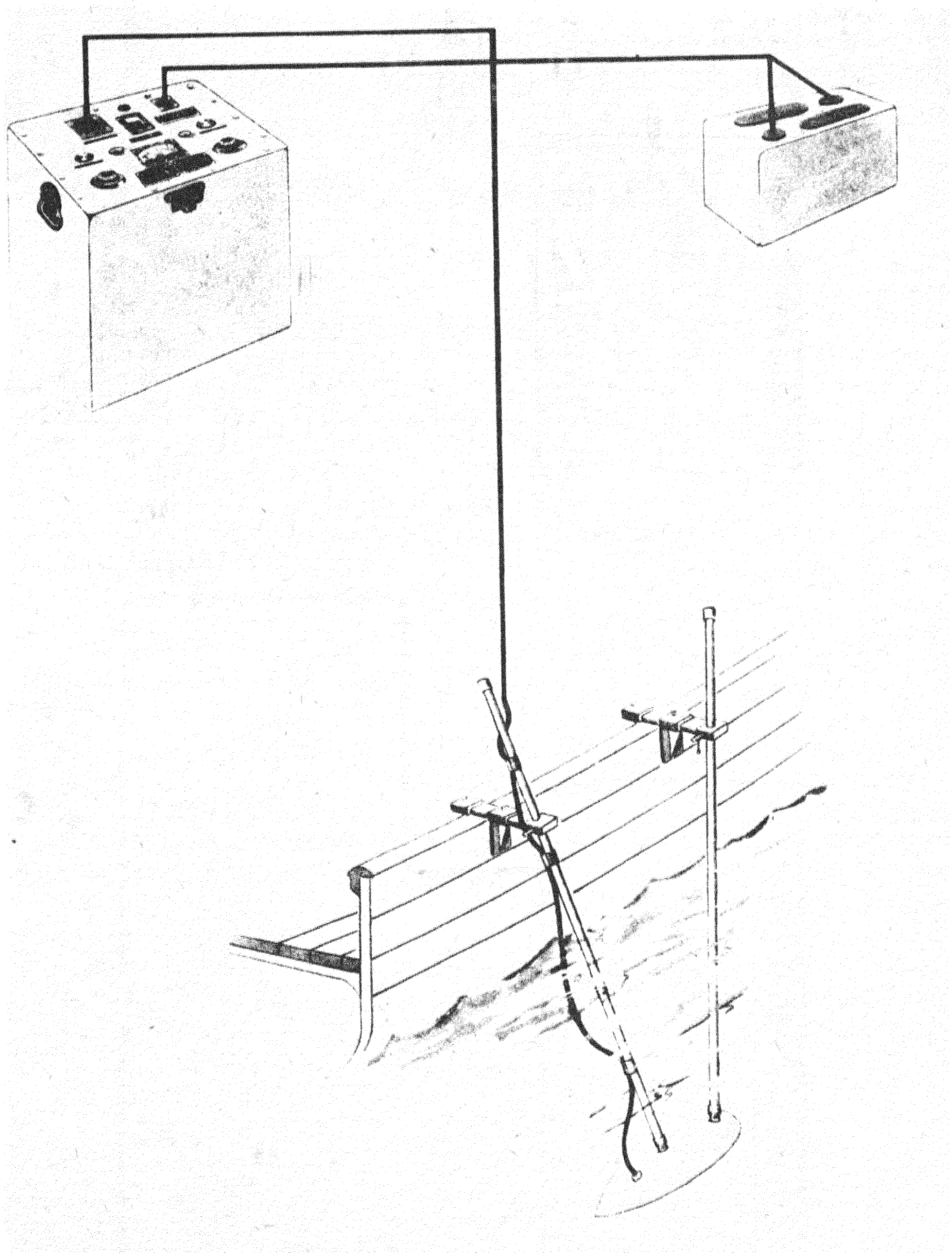


FIGURE 1-1
MODEL NK-5 ECHO SOUNDING EQUIPMENT

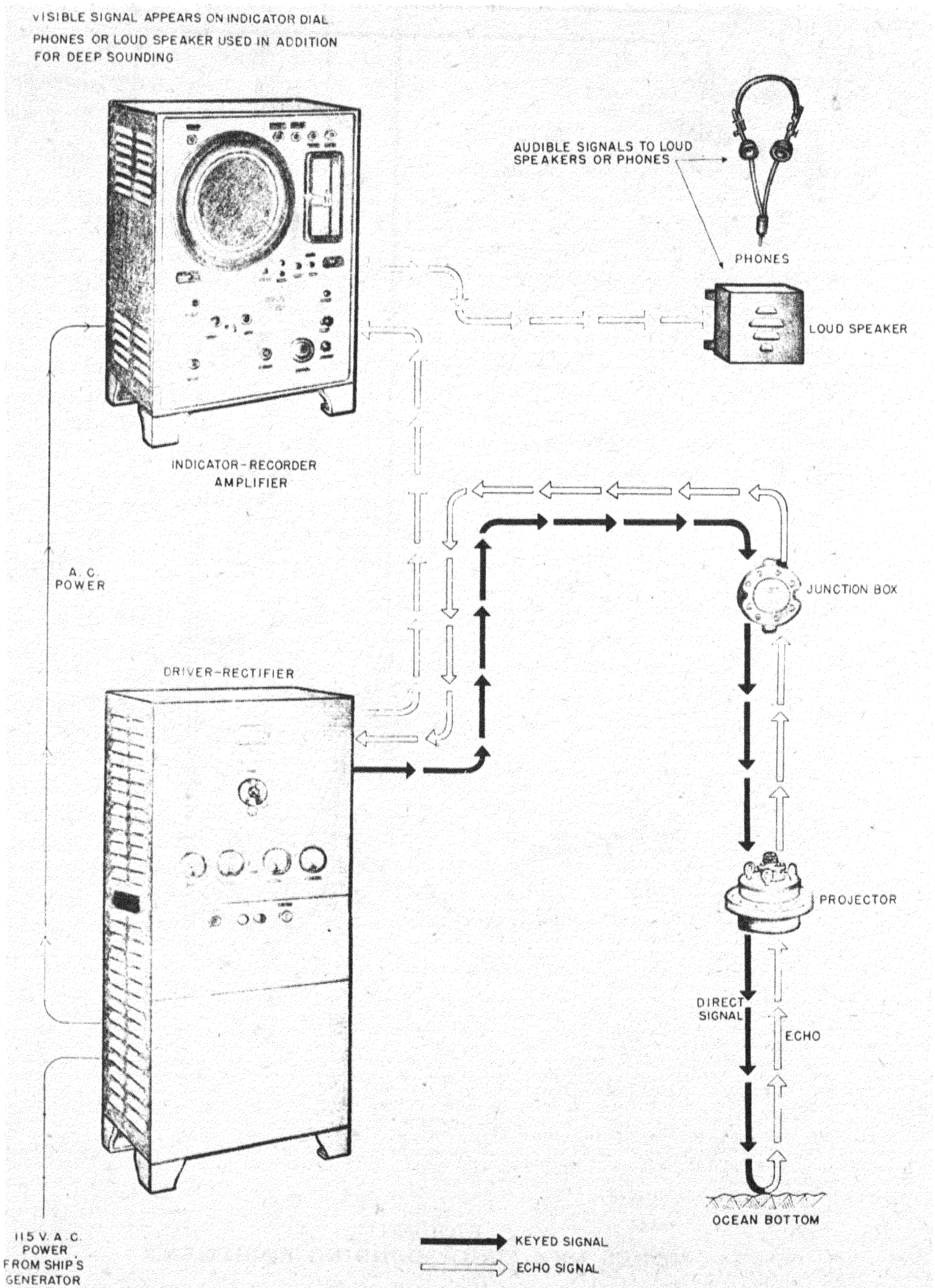


Figure 1-1—Equipment Pictorial

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN. · · · APRIL 28 - MAY 9, 1947

U. S. MARINE RADIOBEACONS

- By -

C. N. DANIEL
LIEUTENANT COMMANDER, USCG

ABSTRACT

This paper presents a general outline of the development of the system of U. S. Marine Radiobeacons and covers the operational aspects of the system since its inception including the relationship of component phases which combined form an integrated radio aids to navigation system.

U. S. MARINE RADIOBEACONS

1. United States marine radiobeacons were first placed in commission on May 1, 1921 when three (3) installations were placed in operation in the vicinity of New York Harbor on Ambrose Channel Lightship, Fire Island Lightship and at Sea Girt Light Station. The United States marine radiobeacon system has, since that date been maintained and operated by a single government agency and a total of 197 installations have been made. Not all of this number are now in operation. Discontinuances and changes have been made from time to time to meet the needs of maritime traffic.

2. The present United States Coast Guard marine radiobeacon system includes 185 installations on the Great Lakes, along the coasts of the United States, its territories and at outlying bases. The most northerly and westerly radiobeacon in the system is on St. Paul Island, Alaska in the Bering Sea north of the Aleutian Islands; the radiobeacon on Chacachacare Island between South America and the Island of Trinidad at the entrance to the Gulf of Paria is situated farthest east; and the installation at Cristobal Mole, Canal Zone is most southerly in the system.

3. 154 installations in the system are located at shore stations, 29 are aboard lightships and 2 are installed in lighted buoys. 166 radiobeacons are attended and operate on prescribed schedules while 19 operate continuously as automatic unattended aids to navigation. All but 10 radiobeacons operate on A2 emission (modulated signal). These 10 installations operate on A1 emission (continuous wave), which is a comparative recent change for the benefit of those craft having automatic direction finders and does not detract from serving the needs of the conventional aural type direction finders. A gradual expansion of continuous wave operation can be expected in future years. Marine radiobeacons are available for and are considerably used by aircraft on over-water routes, thus affording joint air and surface craft use of the same radio aid to the elimination of need for separate aerophares and aircraft radiobeacons in a presently crowded radio frequency spectrum.

4. The four basic power outputs of the United States radiobeacon system are classified as Class A, B, C and D with reliable average ranges of 200, 100, 20 and 10 miles respectively. Two (2) radiobeacons in the system have a power output greater than class A to give a reliable average range of 250 miles. Reports of usable reception at distances well in excess of those considered as the reliable average are not unusual. 125 Coast Guard radiobeacons give coverage over tide waters while 60 installations of this Service cover the fresh waters of the Great Lakes.

5. The Dominion of Canada, Department of Transport, and the United States Coast Guard radiobeacon systems are closely coordinated through most friendly cooperation and relationship between the operating agencies concerned. Methods of operation of the two systems are practically the same in all respects so that a mariner traversing the waters of the Dominion of Canada and the United States interchangeably utilizes the services of both systems as if they were operated by a single agency. Operating characteristics of the majority of Dominion of Canada radiobeacons are included in Coast Guard Light Lists and are shown on Coast Guard radiobeacon charts.

6. The considerable number of radiobeacons operated along the coasts of United States and Canada require a method of operation utilizing carefully selected power outputs and frequencies together with a precise schedule of designated minutes for signal transmission in order to give maximum service with a minimum degree of interference within the presently allocated marine radiobeacon band.

7. United States and Dominion of Canada marine radiobeacons operate on the even frequencies of the presently allocated marine radiobeacon frequency band of 285 to 315 kilocycles. Installations within an area are grouped by threes wherever practicable with each installation transmitting on alternate minutes in scheduled 10 minute periods of each hour during clear weather. This arrangement permits a three point radiobeacon fix by the mariner during the scheduled periods in clear weather. Repeated operation on alternate minutes during low visibility without regard to the hourly 10 minute clear weather schedule periods permit bearings to be obtained on a single station no less than once every 3 minutes during fog or other low visibility conditions. The method of operation of U. S. radiobeacons is explained in detail in Coast Guard Light Lists and radiobeacon charts and in U. S. Hydrographic Office publication H.O. 205 titled "Radio Navigational Aids."

8. Distance finding employing the mariners' comparison of the time reception by aural means of synchronized signals emitted from a radiobeacon and a sound fog signal located at the same station was inaugurated at Cape Henry Light Station, Virginia in February, 1929. This method of distance finding has proven quite satisfactory and at the present time 111 Coast Guard radiobeacons are synchronized with sound fog signals at the same station to give this service. Full explanation of the distance finding feature is covered in the publications mentioned above.

9. Radiobeacon installations within the Coast Guard are fully standardized with respect to electronics equipment involved. Service tested and proven apparatus changes are continually being incorporated in existing and newly established stations to provide simplified installations of the most reliable nature. Recent technical improve-

ments include the use of vertically polarized emissions to reduce "night effect." Stabilized modulation and radio frequencies to permit improved audio and radio selectivity are being provided to combat atmospherics and interference.

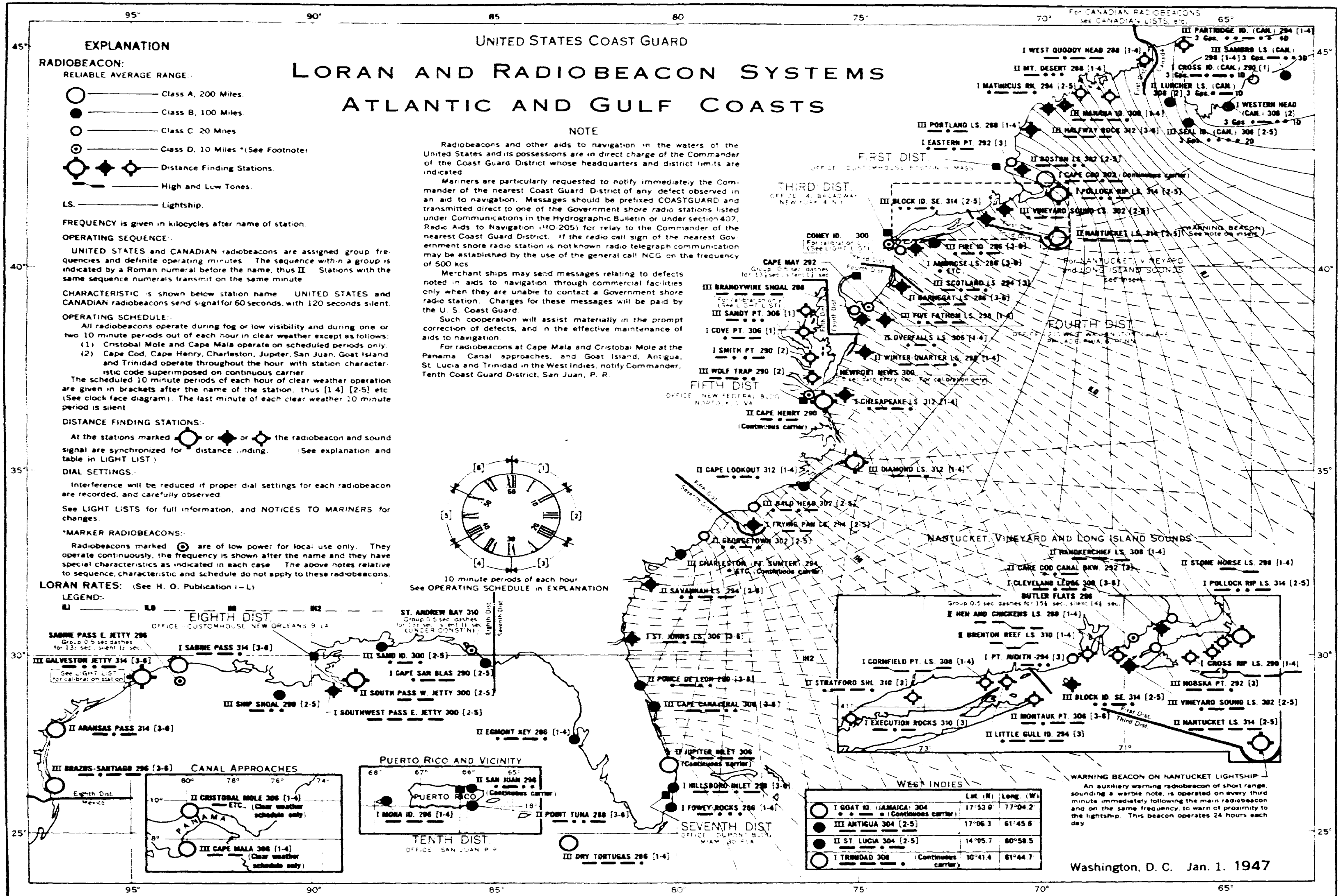
10. The operation of the marine radiobeacons are under constant surveilance by a system of monitoring utilizing radio stations in the Coast Guard communication net work and a few specially designated monitor stations at favorably situated units. Monitoring is accomplished from 39 stations each provided with specialized equipment. These monitor stations make systematic checks for signal failure, frequency variance, faulty signals, emission of signals beyond the tolerable limits of designated operating minutes, strength of signal, speed of transmission, etc. Monitoring provides a means of expediting correction in defective radiobeacon operation and aids in the disseminating of information as necessary to marine interests through radio broadcasted and printed notices to mariners. Monitor station reports are summarized each month and these summaries condensed in one form or another are published to radiobeacon stations in various areas to appraise each other of their performance records. This has been found to create a friendly competitive spirit between individual radiobeacon station personnel to the benefit of efficient and reliable operation of Coast Guard radiobeacons as a whole.

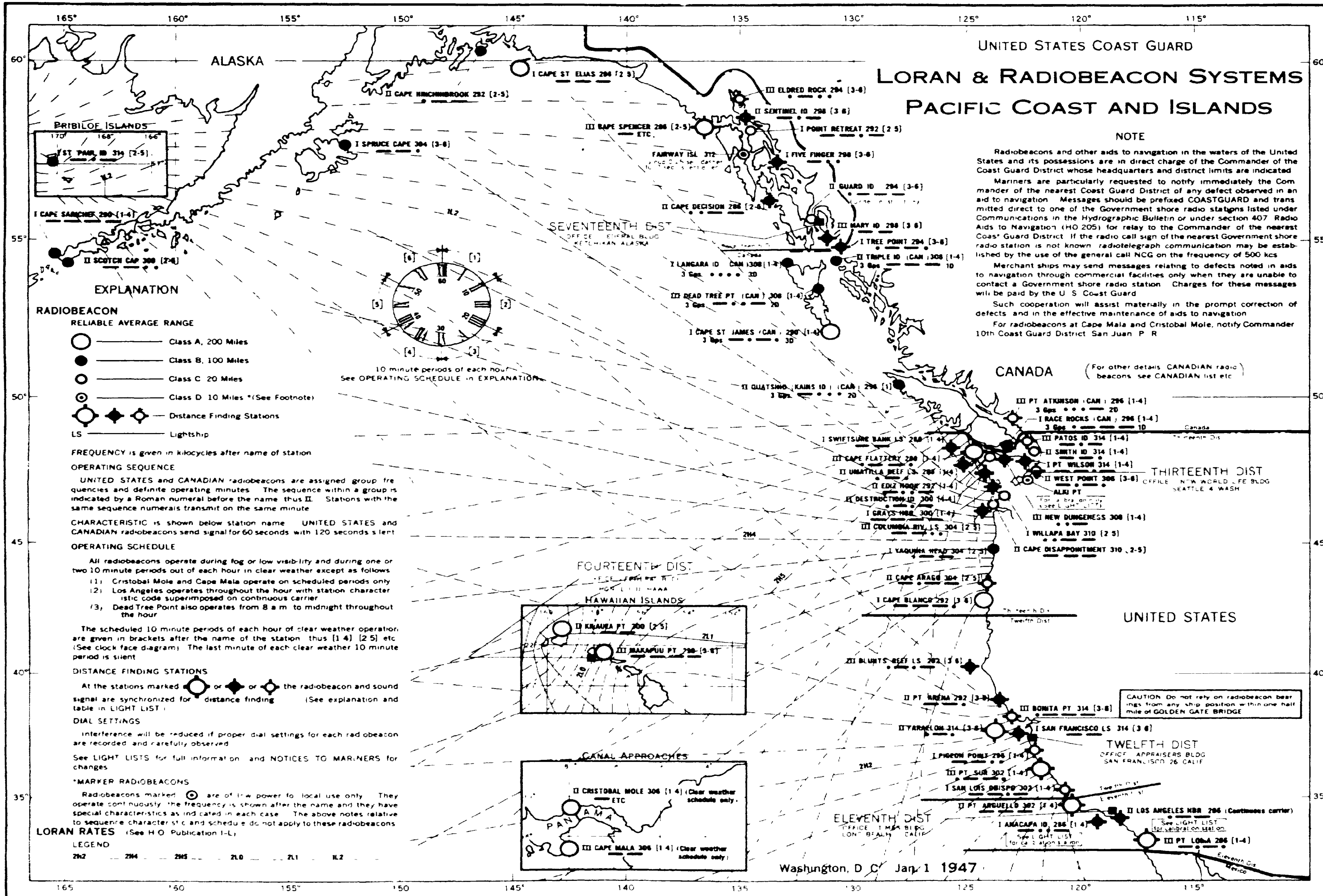
11. United States marine radiobeacons also operate for radio direction finder calibration purposes on request. Transmission for such purposes is continuous without the silent 2 minute interval unless another station in the same frequency group is in operation at the time. Continuous operation for calibration cannot be undertaken during regular schedule periods of radiobeacon operation. Requests for this service can be made direct to the station by telephone, telegraph, or a whistle signal consisting of three long blasts followed by three short blasts repeated until the requested station commences transmission for calibration. The same group of signals are to be sounded at the termination of calibration. A flag hoist of international code signals "J" over "K" is the proper visual signal to display for request for radio direction finder calibration service if attention of the radiobeacon station is not attracted by the whistle signals.

12. The names, locations and operating characteristics of United States marine radiobeacons are published in Coast Guard and Navy Hydrographic Office Light Lists and in Navy publication H. O. 205. Similar data is also shown on the three radiobeacon charts issued by the Coast Guard. Reduced copies of the 1947 edition of these charts included with this paper show Loran coverage over Atlantic and Pacific coastal areas as an added feature. Full size multicolor charts are distributed without charge each year to maritime interests on an automatic mailing list and on separate request.

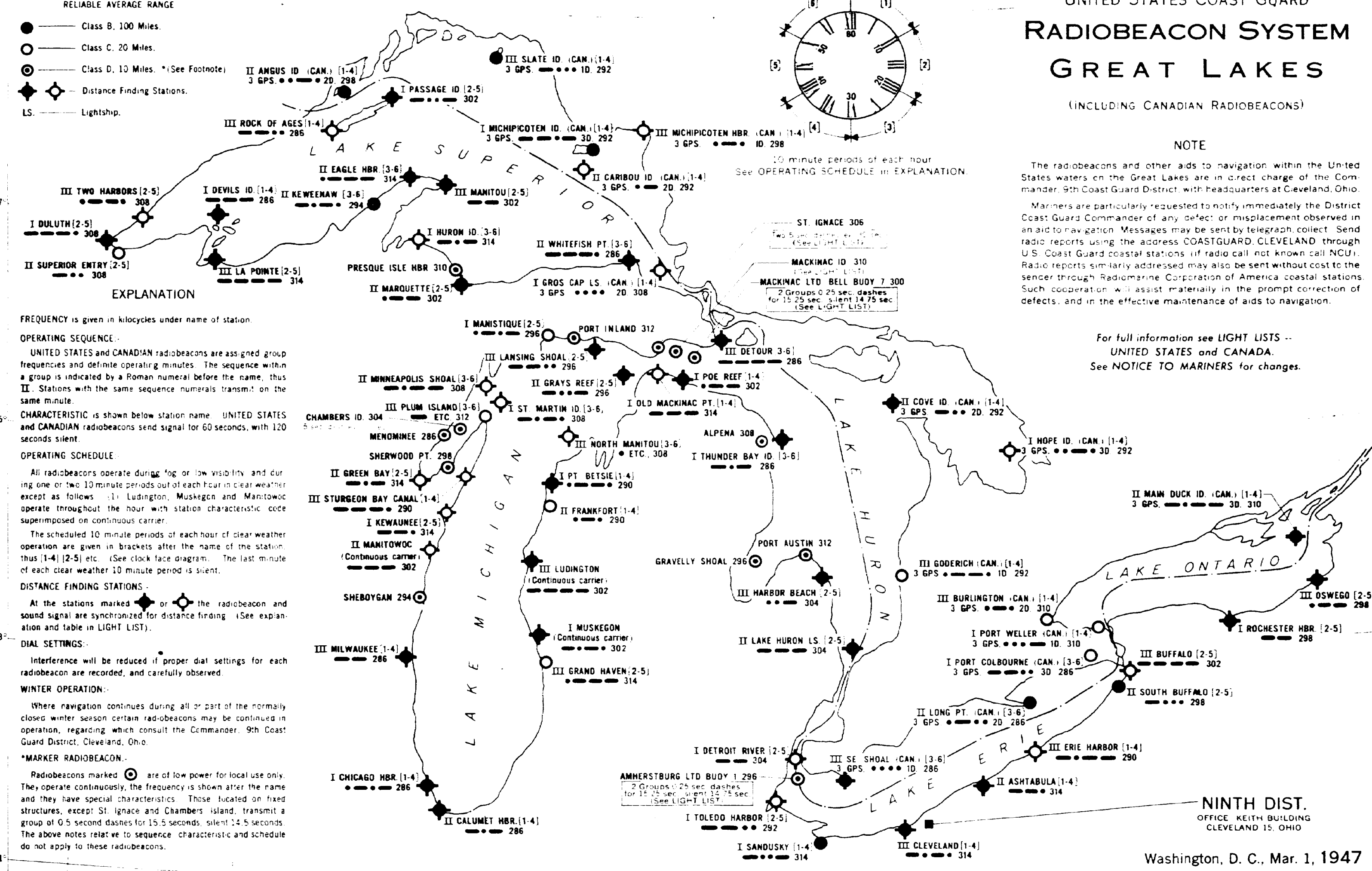
The reduced size charts are included in Coast Guard Atlantic, Pacific and Great Lakes Light Lists which are sold through the Superintendent of Documents, Washington, D. C., and his authorized sales agents. Lists of the sales agencies are published from time to time in United States Hydrographic Office notices to mariners and other publications of that agency.

C. N. DANIEL
LIEUTENANT COMMANDER, USCG


UNITED STATES COAST GUARD
LORAN AND RADIOBEACON SYSTEMS
ATLANTIC AND GULF COASTS
EXPLANATION
RADIOBEACON:
RELIABLE AVERAGE RANGE:
Class A, 200 Miles.
Class B, 100 Miles.
Class C, 20 Miles.
Class D, 10 Miles *(See Footnote)
Distance Finding Stations.
High and Low Tones.
LS. Lightship.
FREQUENCY is given in kilocycles after name of station.
OPERATING SEQUENCE:
UNITED STATES and CANADIAN radiobeacons are assigned group frequencies and definite operating minutes. The sequence within a group is indicated by a Roman numeral before the name, thus II. Stations with the same sequence numerals transmit on the same minute.
CHARACTERISTIC is shown below station name. UNITED STATES and CANADIAN radiobeacons send signal for 60 seconds, with 120 seconds silent.
OPERATING SCHEDULE:
All radiobeacons operate during fog or low visibility and during one or two 10 minute periods out of each hour in clear weather except as follows:
(1) Cristobal Mole and Cape Mala operate on scheduled periods only.
(2) Cape Cod, Cape Henry, Charleston, Jupiter, San Juan, Goat Island and Trinidad operate throughout the hour with station characteristic code superimposed on continuous carrier.
The scheduled 10 minute periods of each hour of clear weather operation are given in brackets after the name of the station, thus [1-4] [2-5] etc. (See clock face diagram). The last minute of each clear weather 10 minute period is silent.
DISTANCE FINDING STATIONS:
At the stations marked or or the radiobeacon and sound signal are synchronized for distance finding. (See explanation and table in LIGHT LIST.)
DIAL SETTINGS:
Interference will be reduced if proper dial settings for each radiobeacon are recorded, and carefully observed.
See LIGHT LISTS for full information, and NOTICES TO MARINERS for changes.
*MARKER RADIOBEACONS:
Radiobeacons marked are of low power for local use only. They operate continuously, the frequency is shown after the name and they have special characteristics as indicated in each case. The above notes relative to sequence, characteristic and schedule do not apply to these radiobeacons.
LORAN RATES: (See H. O. Publication 1-L)
LEGEND:
NOTE
Radiobeacons and other aids to navigation in the waters of the United States and its possessions are in direct charge of the Commander of the Coast Guard District whose headquarters and district limits are indicated.
Mariners are particularly requested to notify immediately the Commander of the nearest Coast Guard District of any defect observed in an aid to navigation. Messages should be prefixed COASTGUARD and transmitted direct to one of the Government shore radio stations listed under Communications in the Hydrographic Bulletin or under section 407, Radio Aids to Navigation (HO-205) for relay to the Commander of the nearest Coast Guard District. If the radio call sign of the nearest Government shore radio station is not known radio telegraph communication may be established by the use of the general call NCG on the frequency of 500 kcs.
Merchant ships may send messages relating to defects noted in aids to navigation through commercial facilities only when they are unable to contact a Government shore radio station. Charges for these messages will be paid by the U. S. Coast Guard.
Such cooperation will assist materially in the prompt correction of defects, and in the effective maintenance of aids to navigation.
For radiobeacons at Cape Mala and Cristobal Mole at the Panama Canal approaches, and Goat Island, Antigua, St. Lucia and Trinidad in the West Indies, notify Commander, Tenth Coast Guard District, San Juan, P. R.
10 minute periods of each hour
See OPERATING SCHEDULE in EXPLANATION
[1]
[2]
[3]
[4]
[5]
[6]
For CANADIAN RADIOBEACONS see CANADIAN LISTS, etc.
FIRST DIST
THIRD DIST
FOURTH DIST
FIFTH DIST
SEVENTH DIST
EIGHTH DIST
TENTH DIST
I WEST QUODDY HEAD 298 [1-4]
II MT. DESERT 298 [1-4]
I MATINICUS RK. 294 [2-5]
III PORTLAND LS. 288 [1-4]
I EASTERN PT. 292 [3]
III BLOCK ID. SE. 314 [2-5]
CONEY ID. 300
CAPE MAY 292
III BRANDYWINE SHOAL 298
III SANDY PT. 306 [1]
I COVE PT. 306 [1]
I SMITH PT. 290 [2]
III WOLF TRAP 290 [2]
II CAPE HENRY 290
(Continuous carrier)
I CHESAPEAKE LS. 312 [1-4]
II CAPE LOOKOUT 312 [1-4]
III DIAMOND LS. 312 [1-4]
III BALD HEAD 302 [2-5]
I FRYING PAN LS. 294 [2-5]
II GEORGETOWN 302 [2-5]
III CHARLESTON LT. SUMTER 294
III SAVANNAH LS. 294 [2-5]
I ST. JOHNS LS. 306 [3-6]
II PONCE DE LEON 290 [3-6]
III CAPE CANAVERAL 306 [3-6]
II JUPITER INLET 306
(Continuous carrier)
I HILLSBORO INLET 288 [3-6]
I FOWEY ROCKS 286 [1-4]
II POINT TUNA 288 [3-6]
III DRY TORTUGAS 286 [1-4]
II EGMONT KEY 286 [1-4]
ST. ANDREW BAY 310
III SAND ID. 300 [2-5]
I CAPE SAN BLAS 290 [2-5]
II SOUTH PASS W. JETTY 300 [2-5]
I SOUTHWEST PASS E. JETTY 300 [2-5]
III SHIP SHOAL 290 [2-5]
I SABINE PASS 314 [3-6]
SABINE PASS E. JETTY 296
III GALVESTON JETTY 314 [3-6]
II ARANSAS PASS 314 [3-6]
III BRAZOS-SANTIAGO 296 [3-6]
CANAL APPROACHES
II CRISTOBAL MOLE 306 [1-4]
(Clear weather schedule only)
III CAPE MALA 306 [1-4]
(Clear weather schedule only)
PANAMA
PUERTO RICO AND VICINITY
II SAN JUAN 296
(Continuous carrier)
I MONA ID. 296 [1-4]
PUERTO RICO
WEST INDIES
		Lat. (N)	Long. (W)
I GOAT ID. (JAMAICA) 304	(Continuous carrier)	17°53.0	77°04.2
III ANTIGUA 304 [2-5]		17°06.3	61°45.6
II ST. LUCIA 304 [2-5]		14°05.7	60°58.5
I TRINIDAD 308	(Continuous carrier)	10°41.4	61°44.7
NANTUCKET, VINEYARD AND LONG ISLAND SOUNDS
II HANDKERCHIEF LS. 308 [1-4]
II CAPE COD CANAL BKW. 292 [3]
I CLEVELAND LEDGE 308 [3-6]
BUTLER FLATS 296
II HEN AND CHICKENS LS. 298 [1-4]
II BRENTON REEF LS. 310 [1-4]
I PT. JUDITH 294 [3]
I CORNFIELD PT. LS. 308 [1-4]
II STRATFORD SHL. 310 [3]
I EXECUTION ROCKS 310 [3]
II MONTAUK PT. 306 [3-6]
II LITTLE GULL ID. 294 [3]
III BLOCK ID. SE. 314 [2-5]
II STONE HORSE LS. 298 [1-4]
I POLLOCK RIP LS. 314 [2-5]
I CROSS RIP LS. 298 [1-4]
III NOBSKA PT. 292 [3]
III VINEYARD SOUND LS. 302 [2-5]
II NANTUCKET LS. 314 [2-5]
WARNING BEACON ON NANTUCKET LIGHTSHIP
An auxiliary warning radiobeacon of short range, sounding a warble note, is operated on every third minute immediately following the main radiobeacon and on the same frequency, to warn of proximity to the lightship. This beacon operates 24 hours each day.
Washington, D. C. Jan. 1. 1947


UNITED STATES COAST GUARD
LORAN & RADIOBEACON SYSTEMS
PACIFIC COAST AND ISLANDS
NOTE
Radiobeacons and other aids to navigation in the waters of the United States and its possessions are in direct charge of the Commander of the Coast Guard District whose headquarters and district limits are indicated
Mariners are particularly requested to notify immediately the Commander of the nearest Coast Guard District of any defect observed in an aid to navigation Messages should be prefixed COASTGUARD and transmitted direct to one of the Government shore radio stations listed under Communications in the Hydrographic Bulletin or under section 407 Radio Aids to Navigation (HO 205) for relay to the Commander of the nearest Coast Guard District If the radio call sign of the nearest Government shore radio station is not known radiotelegraph communication may be established by the use of the general call NCG on the frequency of 500 kcs
Merchant ships may send messages relating to defects noted in aids to navigation through commercial facilities only when they are unable to contact a Government shore radio station Charges for these messages will be paid by the U S Coast Guard
Such cooperation will assist materially in the prompt correction of defects and in the effective maintenance of aids to navigation
For radiobeacons at Cape Mala and Cristobal Mole, notify Commander 10th Coast Guard District San Juan P R
ALASKA
CANADA
(For other details CANADIAN radio beacons see CANADIAN list etc)
UNITED STATES
PRIBILOF ISLANDS
SEVENTEENTH DIST
THIRTEENTH DIST
TWELFTH DIST
ELEVENTH DIST
FOURTEENTH DIST
HAWAIIAN ISLANDS
CANAL APPROACHES
PANAMA
CAUTION Do not rely on radiobeacon bearings from any ship position within one half mile of GOLDEN GATE BRIDGE
I CAPE ST ELIAS 296 [2 5]
II CAPE HINCHINBROOK 292 [2-5]
I SPRUCE CAPE 304 [3-6]
I CAPE SARICHEF 290 [1-4]
II SCOTCH CAP 308 [2-6]
I ST PAUL ID 314 [2-5]
III ELDRED ROCK 294 [3-6]
II SENTINEL ID 298 [3 6]
I POINT RETREAT 292 [2 5]
III CAPE SPENCER 286 [2-5]
FAIRWAY ISL 312
I FIVE FINGER 298 [3-6]
II GUARD ID 294 [3-6]
II CAPE DECISION 286 [2-6]
III MARY ID 298 [3 6]
I TREE POINT 294 [3-6]
I LANGARA ID CAN 308 [1-4]
II TRIPLE ID CAN 308 [1-4]
III DEAD TREE PT CAN 308 [1-4]
I CAPE ST JAMES CAN 290 [1-4]
II QUATSINO KAINS ID CAN 296 [1]
III PT ATKINSON CAN 296 [1-4]
I RACE ROCKS CAN 296 [1-4]
I SWIFTSURE BANK LS 286 [1 4]
III CAPE FLATTERY 286 [1-4]
II UMATILLA REEF LS 286 [1-4]
III PATOS ID 314 [1-4]
II SMITH ID 314 [1-4]
I PT WILSON 314 [1-4]
II WEST POINT 306 [3-6]
ALKI PT
II EDIZ HOOK 292 [1-4]
II DESTRUCTION ID 300 [4-4]
I GRAYS HBR 300 [1-4]
III COLUMBIA RIV LS 304 [2 5]
III NEW DUNGENESS 308 [1-4]
I WILLAPA BAY 310 [2 5]
II CAPE DISAPPOINTMENT 310 [2-5]
I YAQUINA HEAD 304 [2 5]
II CAPE ARAGO 304 [2 5]
I CAPE BLANCO 292 [3 6]
III BLUNTS REEF LS 292 [3 6]
II PT ARENA 292 [3-6]
III BONITA PT 314 [3-6]
II FARALLON 314 [3-6]
I SAN FRANCISCO LS 314 [3 6]
I PIGEON POINT 296 [1-4]
III PT SUR 302 [1-4]
I SAN LUIS OBISPO 302 [1-4]
II PT ARGUELLO 302 [1 4]
I ANACAPA ID 286 [1 4]
II LOS ANGELES HBR 286 (Continuous carrier)
III PT LOMA 286 [1-4]
I KILAUEA PT 300 [2 5]
III MAKAPUU PT 298 [3-6]
II CRISTOBAL MOLE 306 [1 4] (Clear weather schedule only)
III CAPE MALA 306 [1 4] (Clear weather schedule only)
10 minute periods of each hour
See OPERATING SCHEDULE in EXPLANATION
EXPLANATION
RADIOBEACON
RELIABLE AVERAGE RANGE
Class A, 200 Miles
Class B, 100 Miles
Class C 20 Miles
Class D 10 Miles *(See Footnote)
Distance Finding Stations
LS Lightship
FREQUENCY is given in kilocycles after name of station
OPERATING SEQUENCE
UNITED STATES and CANADIAN radiobeacons are assigned group frequencies and definite operating minutes The sequence within a group is indicated by a Roman numeral before the name thus II Stations with the same sequence numerals transmit on the same minute
CHARACTERISTIC is shown below station name UNITED STATES and CANADIAN radiobeacons send signal for 60 seconds with 120 seconds silent
OPERATING SCHEDULE
All radiobeacons operate during fog or low visibility and during one or two 10 minute periods out of each hour in clear weather except as follows
(1) Cristobal Mole and Cape Mala operate on scheduled periods only
(2) Los Angeles operates throughout the hour with station characteristic code superimposed on continuous carrier
(3) Dead Tree Point also operates from 8 a m to midnight throughout the hour
The scheduled 10 minute periods of each hour of clear weather operation are given in brackets after the name of the station thus [1 4] [2 5] etc (See clock face diagram) The last minute of each clear weather 10 minute period is silent
DISTANCE FINDING STATIONS
At the stations marked or or the radiobeacon and sound signal are synchronized for distance finding (See explanation and table in LIGHT LIST)
DIAL SETTINGS
Interference will be reduced if proper dial settings for each radiobeacon are recorded and carefully observed
See LIGHT LISTS for full information and NOTICES TO MARINERS for changes
*MARKER RADIOBEACONS
Radiobeacons marked are of low power for local use only They operate continuously the frequency is shown after the name and they have special characteristics as indicated in each case The above notes relative to sequence characteristic and schedule do not apply to these radiobeacons
LORAN RATES (See H O Publication 1-L)
LEGEND
2H2 2H4 2H5 2L0 2L1 1L2
Washington, D C Jan 1 1947

UNITED STATES COAST GUARD
RADIOBEACON SYSTEM
GREAT LAKES
(INCLUDING CANADIAN RADIOBEACONS)



NOTE

The radiobeacons and other aids to navigation within the United States waters on the Great Lakes are in direct charge of the Commander, 9th Coast Guard District, with headquarters at Cleveland, Ohio.

Mariners are particularly requested to notify immediately the District Coast Guard Commander of any defect or misplacement observed in an aid to navigation. Messages may be sent by telegraph, collect. Send radio reports using the address COASTGUARD, CLEVELAND through U.S. Coast Guard coastal stations (if radio call not known call NCU). Radio reports similarly addressed may also be sent without cost to the sender through Radiomarine Corporation of America coastal stations. Such cooperation will assist materially in the prompt correction of defects, and in the effective maintenance of aids to navigation.

For full information see LIGHT LISTS -- UNITED STATES and CANADA. See NOTICE TO MARINERS for changes.

LEGEND

RELIABLE AVERAGE RANGE

- Class B. 100 Miles.
- Class C. 20 Miles.
- Class D. 10 Miles. * (See Footnote)
- Distance Finding Stations.
- LS. Lightship.

EXPLANATION

FREQUENCY is given in kilocycles under name of station.

OPERATING SEQUENCE:-

UNITED STATES and CANADIAN radiobeacons are assigned group frequencies and definite operating minutes. The sequence within a group is indicated by a Roman numeral before the name, thus II. Stations with the same sequence numerals transmit on the same minute.

CHARACTERISTIC is shown below station name. UNITED STATES and CANADIAN radiobeacons send signal for 60 seconds, with 120 seconds silent.

OPERATING SCHEDULE:-

All radiobeacons operate during fog or low visibility and during one or two 10 minute periods out of each hour in clear weather except as follows: (1) Ludington, Muskegon and Manitowoc operate throughout the hour with station characteristic code superimposed on continuous carrier.

The scheduled 10 minute periods of each hour of clear weather operation are given in brackets after the name of the station, thus [1-4] [2-5] etc. (See clock face diagram. The last minute of each clear weather 10 minute period is silent.

DISTANCE FINDING STATIONS:-

At the stations marked or the radiobeacon and sound signal are synchronized for distance finding. (See explanation and table in LIGHT LIST).

DIAL SETTINGS:-

Interference will be reduced if proper dial settings for each radiobeacon are recorded, and carefully observed.

WINTER OPERATION:-

Where navigation continues during all or part of the normally closed winter season certain radiobeacons may be continued in operation, regarding which consult the Commander, 9th Coast Guard District, Cleveland, Ohio.

*MARKER RADIOBEACON:-

Radiobeacons marked are of low power for local use only. They operate continuously, the frequency is shown after the name and they have special characteristics. Those located on fixed structures, except St. Ignace and Chambers Island, transmit a group of 0.5 second dashes for 15.5 seconds, silent 14.5 seconds. The above notes relative to sequence, characteristic and schedule do not apply to these radiobeacons.

Washington, D. C., Mar. 1, 1947

IMMRAN DOC. 19

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN · · · APRIL 28 - MAY 9, 1947

NEW DEVELOPMENTS IN MARINE RADIO DIRECTION FINDERS

- By -

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ABSTRACT

This paper reviews the past and present state of Marine Direction Finding and compares its merit and fields of applications with that of radar and loran.

Marine Direction Finders, while they have incorporated all the design and component progress made in radio in the last 20 years, are still not only working on the same basic principle, but the means of achieving measurements are practically the same as 20 years ago. The author studies some of the reasons for this condition and reviews what seems to limit further progress.

A number of suggestions for improvement follow, with a short discussion of their practicality; use of other parts of the frequency spectrum; use of pulse transmissions to reduce night effect; use of direct reading indications of bearings, and combination of distance measurement with bearing measurements in order to obtain a fix from only one beacon station.

NEW DEVELOPMENTS IN MARINE RADIO DIRECTION FINDERS

Introductory

The technique of the simple loop direction finder operating on medium frequencies is now too well-known to justify repeating, in this paper, information which we are sure is fresh in the minds of all who are interested in this field. Well-known also are propagation effects, deviations caused by the ship's structure, and deviations due to other causes.

It is only for the purpose of presenting an evolutionary perspective of the technique since the beginning of the century that in the first chapter the development of the Marine Direction Finder is reviewed; and that the progress made by direction finding technique in general, for other applications is reviewed.

It seems important, to us, to compare the Marine Direction Finder with the new radio aids which were developed during the war, as a means of determining the causes for, what seems to be, an over-stabilization of design; and, as indicated by the title of this paper, to survey possible new developments in the field which may make the Marine Direction Finder a still more useful instrument of navigation.

I. The Marine Direction Finder Evolution and Present State of the Art

The direction finder is the oldest radio aid to navigation. Either under the form of the small rotatable loop, or before that under the the form of the large, fixed crossed loop, the direction finder of the pioneers in the art, was the first instrument making use of the directive properties of electromagnetic waves to determine the position of a mobile, or the origin of a radio transmission. Early disclosures before World War I give the names of Stone-Stone, Bellini-Tosi and Blondel among the first to invent, to propose and to try radio direction finding systems. Later Watson-Watt, Mesny, Adcock, Smith-Rose and many others continued to establish the foundations of the new science; by studying propagation and polarization effects, deviations, reflections, etc.

Now direction finders exist, or can be designed, to cover accurately all the frequency spectrum in which radio transmissions are taking place. They are fixed or mobile. Indications are very often obtained in a direct reading manner, through a mechanical pointer on a fixed scale (aircraft radio compass), or in an instantaneous manner on the screen of a cathode ray tube, (fixed short-wave direction finder).

The Marine Direction Finder for shipboard installation was made practical when radio amplifiers became available after World War I. In the United States the early work of Dr. Kolster, who in 1913 was already pushing the installation of shore radio beacons, resulted in demonstrating

the radio compass and position finder on board the U.S.L. T. Tulip (Coast Guard) in June 1921. In 1923, Marine Direction Finders were placed on the market by the Federal Telegraph Company at Palo Alto. They consisted, basically, of a rotatable shaft which carried a pointer moving in front of a magnetic compass dial. Remarkable enough, in spite of all progress made in radio since that time, all the Marine Direction Finders now on the market in the United States consist basically of hand operated rotatable loops; the pointer actuated by the shaft moves in front of a fixed scale or a scale controlled by a repeater from the gyro compass. These direction finders cover the frequency range of 285-315 Kc. assigned to this service. The frequency range is often extended to 500 Kc., to permit taking bearings on other ship transmissions and other fixed stations transmitting within this extra band. The operator observes the bearing of the radio beacon by finding the positions of the loop corresponding to the nulls of signal of the well-known figure "8" directive pattern of the loop collector. Proper design, balance of the loop, sensitivity of the receiver, etc., will determine the sharpness of the null and the quality of the direction finder. Deviations caused by the ship structures, which may run as high as $\pm 15^{\circ}$, are compensated for by a mechanical corrector incorporating a cam adjusted according to deviations determined during the calibration process. The elimination of sense ambiguity is obtained through the transformation of the figure "8" diagram into an approximate cardioid diagram resulting from the effect obtained from a small vertical antenna.

The modern marine direction finder of the rotatable loop type, using either a selective TRF or a superheterodyne receiver, is a reliable instrument which, when well-maintained, will provide readings with an accuracy of $\pm 1^{\circ}$ in 70 or 80% of the bearings, and 2 or 3° for the rest of the bearings, after calibration. Ranges up to 100 or 150 miles on medium power beacons are currently obtained. Recalibrating after months of use will not show more than $1/2^{\circ}$ or 1° difference from previous calibration; if proper precautions are taken not to modify the superstructure of the ship near the loop.

Abroad, the principle of fixed loops and rotatable goniometers of the old Bellini-Tosi type has often been used; as well as the rotatable loop principle.

Efforts were made as early as 1926 to render the operation of direction finders automatic, in which case the operator need only to tune the receiver to the desired radio beacon and then to observe the position of a needle on a scale indicating the bearing directly. In 1929, a direction finder of the automatic type, developed by the Laboratories of the I.T.& T. system in Paris, was demonstrated on a small private ship in Mediterranean waters. It furnished a complete, direct 360° indication without sense ambiguity. A few years later, a series of about 25 of such automatic direction finders were installed for normal service on ships of the Portugese Navy. While their maintenance was heavy, the principle of automatic operation without sense ambiguity was completely achieved. In spite of these early efforts, no Marine Direction Finder of the automatic type is presently in practical use, as far as our information goes. This is undoubtedly due to two causes:

1. The apparatuses built by the first experimenters were costly and probably too complicated for normal maintenance.

2. The simplicity of operation and the reliability of the rotatable type of loop direction finder was such, that there was very little incentive to change to the automatic scheme.

The simplicity of the radio beacon is probably also the reason which limited the progress and application of more elaborate types of transmission; such as pulse transmissions, which have allowed for discrimination between direct wave and the ground wave, thus eliminating part or all of the night error which limits the range of direction finding at night. Considerable research and design work was made in the field of short wave and ultra short wave direction finding prior to and during World War II. This resulted in a considerable improvement in the operation of short wave fixed direction finders. During the war the United States Navy installed an important net of such stations. They are now operated by the Coast Guard and can be alerted in case of distress.

The Army Air Forces and the Air Transport Command also installed hundreds of instantaneous cathode ray indicator direction finders, for the purpose of guiding and rescuing aircraft, before any other long range navigation system was available. On the eastern seaboard of the United States a net of SCR-291 direction finders can be alerted in case of distress. Medium wave Adcock fixed direction finders susceptible to high accuracy at night are also available.

The night effect is the main limitation of medium wave direction finders of the loop type. Direction finders, of course, are not the only radio aids to navigation which suffer from the effects of sky waves reflected by the "E" and "F" layers of the ionosphere. Solutions to the problem of night effect which have been applied to shore direction finding stations have been, so far, not applicable to shipboard installations, because of the size and dispositions of the antenna system. Night range is, therefore, limited to something of the order to 50 miles. In the last chapter of this paper we will come back to this problem and discuss possible improvements.

We shall summarize this chapter in stating that the first radio aid to navigation, the Marine Direction Finder, is a reliable and simple instrument, still making use of the rotating loop, and means of indication of the same type as was used 20 years ago.

II. A Comparison of Merit and Field of Application with Radar and Loran

As a result of the inventions and progress made in timing systems, radar and loran, during World War II, the Marine Direction Finder seems to be subjected to considerable competition from these two systems. The opinion that the direction finder could become unimportant gained some momentum at the end of 1945 and during 1946, when the first releases of the new radio aids were made public. At the present time, the situation is much clarified; the performances of radar and loran are well understood. A detailed examination of fields of application shows that Marine Direction Finders and marine radar and loran are complementary systems, solving different problems of navigation,

with some advantageous overlapping in some cases. Marine radar is a short range radio aid to navigation, primarily fitted for anti-collision, and for pilotage near the shore or at the entrance to and inside of harbors. A range of 10 to 20 miles is a reasonable figure for what can be achieved in these applications. Loran, on the other hand, is a long range (up to 750 miles), accurate navigation system, the operation of which for the determination of a "fix", requires somewhat more training and more time than the direction finder. The main question is one of world availability of loran signals and world standardization, as operators will have to contend with stations installed in foreign territories, in many instances. Therefore, the Marine Direction Finder with a day range of the order of 150 miles, is a very excellent intermediate-distance aid to navigation which can bring a ship, with desired accuracy, within the range of operation of the marine radar. The advantage of the direction finder, for intermediate distance navigation, is simplicity, ease of maintenance, availability and the cheapness of the radio beacon ground set-ups. About 190 radio beacons are installed on the shores of the United States and around the Great Lakes. Another 400 are operating throughout the rest of the world. Many countries can increase the services made available to their shores at moderate expense.

We shall conclude this section by repeating the more or less accepted opinion that Marine Direction Finders, radar and loran, are complementary systems, that availability of loran transmissions will certainly be the largest factor which will determine its generalized use, and that the way radar is collecting its information, independently of ground or other ship cooperation, is the essence of its assured success.

III. The Present Crystallization of Design of the Marine Direction Finder

In the first section, showing briefly the evolution and the present state of the art, we stated that the present Marine Direction Finder is more or less crystallized around the principle of the rotatable loop hand-controlled, and that the means of measurement by observation of the nulls of the figure of "8" directive pattern is the same means of observation as was used 20 years ago; in spite of the extraordinary development of radio communication and radio navigation during the same period. The art of direction finding as a whole, has progressed during the war to the point where techniques and instruments are available, or could be made available, in the entire frequency spectrum of radio waves; propagation studies have taken place which improved our knowledge of propagation greatly. Indicating means also have been considerably improved; the automatic aircraft compass equips almost every aircraft; even the large ships carry two or three such instruments. Shore direction finders are making use of cathode ray tubes for instantaneous presentation of bearings to the operator. Ultra-high-frequency direction finders are used in connection with airport traffic control. Moreover, investigating the patent literature is most revealing; the field of direction finders has not been neglected at all by inventors. There seems to be no relation between the crystallization of design and the very large number of systems which have been invented. We shall try to list below the factors which seem to limit introduction of new designs and ideas in Marine Direction Finding:

1. The reliable simplicity of the present design.

2. The availability of a world-wide set-up of marine radio beacons.

3. The simplicity of the ground beacons and their consequent cheap cost.

4. The reluctance to introduce, and difficulty in introducing changes in the existing world-wide radio beacon set-up, which would facilitate the adoption of improvements in Marine Direction Finder design.

5. Perhaps, also, the concentration of the attention of laboratories and manufacturers to the problems of radio aids to air navigation.

Let us next consider whether we have reached a condition where further progress can be obtained at reasonable cost; or, whether some new approaches can make the direction finder a still more useful and attractive instrument for navigation.

IV. New Approaches Resulting from Determined Departure from Existing Solutions

The following questions will be examined:

1. Is the present frequency range of 290-310 Kc. the most advantageous for this service, or could the use of another part of the frequency spectrum result in improved performance with respect to accuracy, range or reduction of the night effect?

Lower frequencies eliminate themselves because their inherent characteristics demand increased costs of theground stations required, and because of the probable lack of such frequencies for this purpose; therefore, higher frequencies are suggested. Our experiences in the field of shipboard H.F. direction finders leads us to reject that spectrum for the application. Ultra-high-frequencies would definitely be free from night effect but the range would be limited by line-of-sight conditions; the UHF wave collector would have to be installed on the top of the ship's mast in order to obtain a 20 mile range from a transmitter not very high above sea level. In spite of a very probable increase of accuracy and the elimination of night effect, it seems quite improbable that this would compensate for the increase of cost and, more improbable, for the shortening of the range. The incentive for any group to develop a UHF direction finding system on such a fragile foundation is certainly too weak to tempt a manufacturer to experiment in that direction.

2. Would an instantaneous direct reading indicator of simple design, increase efficiency sufficiently to make it appear attractive to the ship operators and to the ship owners, and to subsequently justify an effort for its development and adoption?

Navigating along the east coast of the United States, where beacons are arranged by groups of three on the same frequency, transmitting sequentially by units of three minutes, tends to demonstrate that an instantaneous indicator, giving successively the bearings of the three stations, would be quite justified on the basis of simplification of procedure. A computer could be designed to facilitate either the recording or the plotting of the "fix". The type of indication should be such that a failure would be immediately detectable. It could be a mechanical pointer, a neon or other gas tube or a cathode ray tube; however, the simplest and most reliable instrument would be preferred. In connection with such an indicating system, a null seeking loop or goniometer, or a small continuously rotating loop or goniometer is generally required. While a complete direction finder of such type has not yet been installed for service tests on board a merchant ship, various components performing equivalent functions have been tested during other developments and results have proved reliability.

This will be an important factor in the choice of the many possible solutions which offer themselves for direct reading direction finding. The preferred solutions will be the using of instruments for which a good quantity of data on reliability is already available. Among such we find the null-seeking type of direction finder with mechanical pointer, the rotating loop or goniometer with cathode ray tube presentation and the neon tube indicator, or meter indicator.

Other methods (those avoiding rotating parts) involve electronic goniometers, or various modulation schemes eliminating the need for three channel receiving systems.

Generally speaking, whatever the method used to get the directive information through one receiving system, the indicator can be of any of the three most important classes just mentioned.

There is room for ingenuity in design to satisfy the useful requirement of simplification of procedure.

3. Could more stability in the transmitter and in the receiver permit utilizing channeling principles, as used in communication systems or as proposed for other navigation systems?

The resulting simplification of the tuning of the receiver on the radio beacon should rightly be an added feature of a direct reading direction finder. Convenient stability has already been achieved in many beacons and the cost of stability in the receiver could be kept reasonably low.

This has another aspect. The band width generally agreed upon at present in direction finder receivers is many times larger than necessary, even for the purpose of identification of the radio beacon. The audio frequency modulation of the beacon is not basically required. Provided sufficient stability is assured in the transmitter and in the direction finder receiver, the present band width of the direction finder receiver could be decreased ten fold; which is equivalent to an increase of ten times the transmitter power. Much further improvement would still be possible, but might require costlier design. Further advantage can be derived from

this increase of sensitivity by increasing the accuracy and stability of the direct reading direction finder.

Very small band widths, of the order of 20 radio frequency cycles, are being tried in connection with present developments of Long Range Navigation systems.

4. Could night effect be reduced by the use of pulse transmissions?

Pulse transmission for the purpose of discriminating between the ground wave and the sky wave was proposed and tested in Germany prior to the war. Expected results were obtained; the disadvantage being in the band width required for the transmission. The circuits to separate the ground waves from the sky waves in the receiver would be definitely more expensive and complicated to maintain than the simple circuits of the present receivers. In spite of its promising aspects, this system would require a considerable amount of further development before a sound opinion could be formed concerning its practicable value. It is still doubted that such an improvement resulting from increased range at night would justify itself. However, the question would merit much more detailed consideration if the pulse transmission from the ground beacon could be taken advantage of for the purpose of distance measurement.

Any such modification of the present radio beacon set-up on a world wide basis, would meet all the difficulties of application that we can readily imagine, and would contribute to discouraging the inventor or the manufacturer.

5. Is the combination of the Marine Direction Finder with some distance measuring system desirable and/or possible?

In air navigation the R-Theta system has reached justified success due to many advantages, two very important ones being, (1) that a complete "fix" can be obtained from one station and supposedly from one transmission, and (2) that the accuracy of a "fix" is the same for the 360° coverage of each station. Distance measuring equipment making use of ultra-high-frequencies would not be of much assistance to the Marine Direction Finder because of its range, limited by the line-of-sight condition. However, one can imagine a medium wave distance measuring system using phase measurement of an audio frequency modulation for the determination of time of travel and, therefore distance. The ship could interrogate the radio beacon on a medium frequency channel assigned for that purpose; the audio signal received at the ground beacon would be re-transmitted through the beacon to the ship, where the audio phase measurement resulting in distance indication would be effected at the output of the direction finder receiver. The drawback to this system is that only one ship at a time would interrogate the beacon; but this interrogation should not need to last more than a number of seconds for each call, and should be limited in time; an indication of the availability of the channel for such interrogation could be provided, with self-identification of own transmission. This distance indication system could be introduced in the form of attachments which would not require world-wide acceptance before

advantages are realized from the first installations. Considerable development work would have to take place to solve properly such a problem and it is very doubtful that a private enterprise would decide to start such a project unassisted.

Conclusions

Among the possible improvements to the Marine Direction Finder which may be recognized in the not too distant future, we see the automatic indication of bearing and a reconsideration of the stability and channeling of radio beacons, for the purpose of improving performance. Moreover, it seems that the combination of the shipboard direction finder with some form of a distance measuring system, would result in an attractive navigation scheme, upon the development of which some imaginative effort could be applied in the next few years. No simple solution is available to eliminate or reduce the night effect at present.

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THE DECCA NAVIGATOR

Report of user and accuracy trials and description of Lane Identification

Summary

Since first I.M.R.A.M.N., the English chain of Decca stations has been established and is in continuous operation. Ships of the Royal Navy and Merchant Marine have been fitted with receiving apparatus, and are making extensive use of the system. As a result of trials, the Ministry of Transport has approved the use of the system for general navigation within 240 nautical miles of London.

Scientific measurements of the accuracy of the system have continued, and an investigation of practical application of the system in the Merchant Marine has shown that the system is of great value, both commercially and in increasing safety at sea. Mariners have given it a very favourable reception.

A comprehensive programme of chart production is well advanced, charts for all areas in the coverage of the present chain will be available this year.

Some examples are given of the practical use of the Decca system made by ships in the course of their ordinary duties.

A method of Lane Identification, which has been successfully demonstrated is described.

Introduction

1. The principles of the Decca Navigational System were described at first I.M.R.A.M.N. (Vol. II of report, p 48) and have also been set out in other publications.

2. In July 1946 three transmitting stations, a "master" and two "slaves" (known as Red and Green), situated in South-east England,

commenced continuous transmissions for use by naval surveying ships and minesweepers and for experimental purposes. A third slave (Purple) was put into operation later in the year and the four stations form a complete transmitting chain giving all round coverage, and designated the English Chain. Royal Navy and Merchant Ships were equipped with Decca receivers and latticed charts were supplied.

3. An investigation of the use of the system in merchant ships was carried out by the Ministry of Transport with full co-operation of shipowner and ships' officers, to assess its practical possibilities. Attention was mainly directed to determining (i) the opinions of ships' officers on the use of the apparatus, (ii) the value of the information given under actual working conditions, and (iii) the use that was made of this information. In addition attention was paid to ensuring that the method of presentation enabled the mariner to make the best use of the system.

4. The Admiralty have continued scientific tests of the accuracy of the system both on the English Chain and on the experimental chain installed earlier on the south coast of England.

5. The Decca system has had a remarkable welcome amongst mariners. The factors responsible for this are first, the high degree of accuracy in fixing position, second the simplicity of operation, and third the rapidity with which a fix may be obtained.

The final criteria of a radio navigational system are whether it will increase safety at sea and justify its use commercially. The indications are that both these conditions are fulfilled by the Decca system.

6. On the basis of the Admiralty investigations into the accuracy of the system, and of operational trials, the system has been approved by the Ministry of Transport for commercial use as an aid to general navigation within 240 nautical miles (440 kilometres of London, which includes the whole of the coasts of England and Wales and the adjacent Continental waters. This approval is subject to measurements of geodetic errors and lattice distortion in the area of each large scale chart before it is issued.

7. It is probable that a chain of Decca stations will be set up in Scotland to give coverage around the Scottish and North of Ireland coasts. The addition of a chain in the vicinity of Denmark would provide continuous cover from any port in the United Kingdom to well into the Baltic Sea.

Operation of Stations

8. The Sites and Frequencies of the four stations in the English chain are:-

Master Station

Near Ware, Hertfordshire — Frequency = 85.000 Kc/s

Red Slave Station

Near Norwich, Norfolk — Frequency = 113.333 Kc/s

Green Slave Station

Near Lewes, Sussex — Frequency = 127.500 Kc/s

Purple Slave Station

Near Wormleighton, Warwickshire — Frequency = 70.833 Kc/s

In addition three monitor stations are operated by the Decca Navigator Company to monitor each lattice pattern. Continuous monitoring of all the patterns is also carried out at an Admiralty station.

9. Fig. 1 shows the positions of the transmitters, the coverage (reckoned from London), and the transmission zones. Each red zone comprises 24 lanes, each green zone 18 lanes, and each purple zone 30 lanes. As it is essential for the transmitters to operate with unbroken transmissions over the 24 hours of each day, three complete transmitters are employed on each station. One is the operating transmitter, one is an immediate standby and has all filaments on and is ready to take over should the operational transmitter fail, and the third is available for maintenance. Automatic relays operate immediately if the working transmitter fails and the standby is brought into service in less than 1½ seconds. In addition, each station is provided with two diesel generators and one petrol generator in case of failure of the public mains power supply. One diesel generator is constantly running in readiness for immediate change-over. Transmitter power output is 2 kilowatts and with an aerial efficiency of 45% the radiated power is 900 watts.

10. During the earlier trials the Master and only the Red and Green slave stations were used, but the Purple slave was brought into use later.

Operation of Equipment

11. During the trials the approximate position of the ship was known either at the beginning of a voyage or at some other convenient point and it was possible to set the meters to the whole number of the lane in which the ship was situated. This setting is made after the receiver has been allowed to warm up by means of a knob and when this is released the fractional pointer immediately indicates the fractional part of the lane, and the exact position of the ship may be determined. As the ship moves the pointers rotate and the lane numbers increase (or decrease by one for each revolution of a pointer, so that a fix may always be obtained from the readings of the meters.

12. Should some disturbance rotate the fractional pointer more than half a revolution, it may return to its original position via the remainder of the arc. In this manner a whole lane may be gained or lost. This phenomenon is referred to as "lane-slipping". Lanes may also be gained or lost at night, should the direct wave and the reflected skywave be of comparable magnitude and out of phase.

13. This possibility of error would be a serious defect in the system, but will be eradicated when the Lane Identification system is established. Lane Identification provides automatic information of the correct lane numbers and the mariner is therefore not dependent on knowing his geographical position in order to set up his meters.

Accuracy Trials.

14. To provide a reliable assessment of the absolute accuracy of the Decca system is difficult, since the errors expected in the system are comparable with those of normal methods of navigation; results obtained in the ordinary course of navigation are therefore suspect. A series of trials is in progress in which the measurements have been made on board surveying vessels, the fixes being of the quality considered satisfactory for hydrographic survey and the result of these trials should be free from uncertainty.

A considerable amount of time is involved in taking such measurements and analysing the results. Full details are not yet available but some preliminary figures may be quoted. Some 48 fixes were taken in the Thames in the region of Tongue Sand Fort (where the lane width is about 920 yards (841 metres) on the Red, and 1200 yards (1104 metres) on the Green Pattern), showing standard deviations of 0.033 of a lane and 0.028 of a lane on the Red and Green Patterns respectively. These observations cover a comparatively small area and in addition to the scatter recorded above, appreciable systematic errors have been

observed; they were of the order of 0.04 of a lane on the Green Pattern. The question of such systematic errors is still under investigation. They may be due merely to local effects at the shore-based Monitor Stations, causing the phase constant of the pattern to be adjusted incorrectly. Another possible cause is the slight disturbances in velocity of propagation due, for example, to variations in the conductivity of the soil. A further source of uncertainty lies in the siting of the transmitting and monitoring stations, since the survey of the United Kingdom was carried out in detail, county by county, before a primary triangulation was available; these detailed surveys were later adjusted to fit the primary triangulations but small errors are known to exist and it is possible for the relative positions of two stations in different survey areas to be in error. This is being checked by direct reference to the new primary triangulations.

16. Until all these points have been cleared up it is impossible to state the maximum accuracy obtainable from the Decca Navigator System, but the investigation shews that it is of the same order as that quoted at first I.M.R.A.M.N. (Vol. II of Report, p. 164 and p. 170), and is ample for coastal navigation. The area which can be covered by one chain, to the standard stipulated for difficult coastal regions, cannot be finally assessed until more information is available.

17. Trials have been carried out at fixed points ashore to assess the stability of the transmitting pattern and of the receiving sets; when the English Chain was first erected some difficulties were experienced but these have now been cleared. Even if the pattern is not monitered, the automatic phase locking system is capable of retaining the pattern within a standard error of .015 of a lane. A receiving set (which can of course be used as a monitor) has a standard error of less than .01 of a lane at a fixed point (instrumental errors due to slight departure from the linear scale law may slightly increase this value for general use. It is apparent from these trials that it is now possible to erect a chain of stations capable of setting up a space pattern of phase of considerable reliability.

18. It is known that the Decca System suffers from appreciable errors when the sky-wave becomes comparable with the ground wave, and if the sky-wave equals or exceeds the ground wave, lanes may be 'slipped'. It is not easy to determine the range at which such effects become important because other factors may introduce errors or 'lane slip'. In particular, Lanes may be slipped with a smaller value of

sky-wave (than is required on the simple theory) if interfering signals are present; such lane slips should not be included in an assessment of the attainable performance, since if the system were internationally adopted, interfering stations would be moved to other frequencies. As the Ionosphere is very variable experiments must be carried out for a very considerable period if really reliable results are to be obtained. So far these difficulties have prevented a very firm estimate of the maximum range being attained, but the results of trials over a comparatively short period, which are summarised in the graph (Fig. 6) showing error in miles against range in miles, show that it is unlikely that lanes will be lost at distances less than 300 nautical miles (556 kilometres). It appears that the meters could not be set up reliably, even if the exact position of the vessel is known, at distances greater than about 250 miles (464 kilometres). For the present it is desirable on evidence available to restrict the use of the system to 240 nautical miles (445 kilometres), but this range will be modified if experience shows this to be necessary.

19. Further scientific trials to obtain more results are planned, since the enthusiastic welcome given by Marine Users to this system shows that a detailed investigation of its performance is worth while.

Use by the Royal Navy

20. Before describing the operational trials on merchant ships an account should be given of the use of Decca by the Royal Navy. The Navy first used the system, in conjunction with Gee and Radar to assist the leading minesweepers of the Normandy invasion fleet to clear a passage through the minefields and enable the landing vessels to make a safe and timely arrival at the right parts of the beaches. At present the Decca system is used by about 24 naval ships including destroyers, survey ships, wreck-dispersal vessels, a fishery-protection vessel, and a cable ship. It has been particularly valuable in laying channel buoys and for fixing the position of submerged wrecks. More ships are being fitted so that more extensive use can be made of the system.

Operational Trials on Merchant Ships

21. Although the transmitters were in operation by July 18th 1946 no merchant ships were then in a position to receive transmissions, but ships were fitted as quickly as possible with three channel receivers (Mark III); the two meters (referred to as Decometers) were fitted on a bracket above the chart table, and the necessary latticed charts were supplied. A representative of the Decca Navigator Company travelled with each ship on its first voyage with Decca equipment, in order to demonstrate the method of use to the ship's officers.

22. The following tables summarise the stages of fitting, and give an overall picture of the scope of the investigation, up to 31st January, 1947, a trial period of six months. Ships fitted after January 3rd have not been considered, as at least four weeks experience with the apparatus was considered necessary for an adequate appreciation to be made.

Type of Vessel	No. of ships fitted with and using Decca system at;					
	July 31	Aug. 31	Sept. 30	Oct. 31	Nov. 30	Jan. 3'47
Passenger	-	1	2	5	5	5
General cargo	-	3	9	14	17	20
Collier	-	3	4	4	5	6
Cable-laying or survey	1	1	1	2	2	2
Total all classes	1	8	16	25	29	33

Most of the ships were small coastal vessels engaged on regular routes. The total tonnage represented by the 36 different ships was of the order of 55,000 tons. The smallest vessel, apart from the survey launch, was 350 tons, and the largest was a passenger liner of 7,000 tons.

23. During the course of the trials the ships travelled from and to practically all the ports of the southern half of Great Britain and the north west coast of Europe. (See Fig. 2.) The regular routes included:

London to: Blyth, the Tyne, Plymouth, Liverpool, Dublin, Calais, Boulogne, Havre, Dieppe, Antwerp, Rotterdam, Oslo, Copenhagen, Hook of Holland, the Channel Islands.

Harwich to: Hook of Holland, Antwerp.
Dover to: Calais
Hull to: Cuxhaven, Oslo, Copenhagen

In all, about 760 voyages from port to port were made, in which the Decca navigator could be used for all or part of the way. These represent a total of about 17,200 hours use.

24. Voyages were made by operational research officers of the Ministry of Transport on the following routes:-

London to: Sunderland, Plymouth, Dublin, Liverpool, Antwerp, Rotterdam.
Harwich to: Hook of Holland
Dover to: Calais
Hull to: Cuxhaven.

and the experience gained was of great assistance in assessing the practical value of the system.

25. Details of the charts used are given in another paper (U.K. Paper No. 19). They are ordinary British Admiralty charts over printed with the Decca lattice. Those principally used on the trials included a medium scale chart of the Southern North Sea, and large scale charts of the Thames Estuary, the Kentish Coast to Calais, the Schelde Estuary, Dunkirk to the Hook of Holland, and the English East Coast.

In addition, two R.A.F. Experimental Charts 'France West and Western Approaches' and 'Great Britain and Eire' (scale 1: 1,000,000) were used, these covering the south and west coasts of England and Wales. These charts are not intended for marine use, as they are of small scale and on a conical projection. However, they were found useful by ships travelling in some areas for which large scale charts were not available, e.g. the Channel Islands. (See Fig. 3 for coverage of charts used in trials).

The Admiralty's programme for 1947 includes production of 50 more Decca charts. With existing charts, these will provide coverage for practically the whole of the seas inside the radius of 240 miles from London. The English East Coast is covered from the Tyne to Dover; the South Coast from Dover to Land's End; and the West Coast, Wales and Irish Sea from Lands End to the Solway Firth. Very large scale charts of important ports, such as London and Liverpool, will be available. The English Channel, and all the north French coast from Morlaix to Dunkirk; the whole of the Belgian coast; the Netherlands coast, including the ZuiderZee, as far as Terschelling; and the adjacent North Sea, will also be covered.

26. Method of Investigation. The methods of collecting information were as follows:-

(i) Ships were supplied with a written questionnaire and log forms; the questionnaire covered the suitability of charts, method of presentation, routine followed in plotting readings, etc; in the

logs, spaces were provided for filling in the Decca fix against the position estimated from other navigational methods.

(ii) Ships were visited in port after they had used the receivers for a month or so. The officers were then invited to express their opinions on the system as a whole, and whether they had any suggestions for the improvement of the charts, instruments, etc., whether the equipment had proved reliable, and if it had been found especially useful on particular occasions.

(iii) Voyages were made by operational research officers over representative routes and in different types of ship, to observe the practical use of the system.

(iv) Information was obtained from reports which several ships sent in in addition to answering the questionnaire. These reports usually dealt with circumstances which had occurred to give the Decca positions special value.

<u>Notes on Installation</u>

27. The equipment was supplied and installed by the Decca Navigator Company. No major difficulties were encountered in the fitting of the sets. If the ships' chartroom was particularly small, and no other space was available, the receiver was clamped to the deckhead instead of being mounted on a shelf. The two Decometers were normally mounted on a bracket above the chart table, and this position was found satisfactory by mariners. The aerial, suspended from the ships' mast, was led straight through the bulkhead or deckhead to the receiver. Non-insulated aerials were used at first, but several instances of 'lane-slipping' in wet weather were attributed to moisture on the aerial insulators providing a leak to ground. They were therefore replaced by completely insulated aerials taken into the chartroom through a dripp proof lead-in. The receivers are constructed to operate directly from 110v D.C. and a voltage dropping register is fitted where the supply is 220v. Because some ships have "floating" mains, it was found desirable to isolate the receiver chassis from D.C. earth. The chassis on which components were mounted was supported inside the case by rubber feet, which both served as shock absorbers and also isolated the chassis electrically.

<u>Methods of Plotting Routes.</u>

28. In the waters in which the Decca system has been tested ships usually follow routes defined by buoys, moored at intervals of a few miles from one another. It is essential for ships to follow these routes closely, as extensive areas of sea are still not clear of mines, and there are numerous partly-submerged wrecks. While such route-buoys exist, the value of the Decca system in good navigation conditions is not as great as it would be if the mariner were free to choose his own route. On the other hand, in emergency it is of great value indeed because of the vital necessity of knowing position with accuracy. The

buoys are useful reference points which mariners may use in fine weather, comparing their positions with those given by the Decca system, and thus obtaining confidence in the reliability of the system. Dur allowance must be made for buoys being out of position, particularly when well out to sea or after rough weather. After some use, ships' officers began to use the Decca fixes for checking buoys positions.

29. All ships using the Decca system on regular routes keep a ships' log of Decometer readings for the buoys, in both good and bad weather. By doing so, the operation of the set is regularly checked, the ships' officers maintain familiarity with the system, information is given when a buoy is out of position, and in emergencies (examples of which are given later) full use may be made of the system. The route is usually laid out on the Decca chart, buoy positions being shown. In small ships no continuous watch is usually made on the Decca Navigator in good sailing conditions, other than the checks at each buoy. In fast passenger vessels an officer may be detailed to maintain a continuous check on the Decca system. This was carried out to great advantage by the s.s. "Royal Daffodil" on the Dover-Calais route, where tides are particularly strong and liable to carry a ship off course. It was necessary to adhere to a strict time schedule, and any deviations from course were of importance; an officer maintained a continuous record of the ship's position on tracing paper laid on top of the chart, and any deviation of the ship from the direct route was immediately apparent and was corrected. By means of a large scale chart (1:4,910) of Dover Harbour, across which the lattice had been drawn, the actual course of the ship in the harbour was plotted to within about twenty yards.

30. Another method of course plotting was devised by the master of the s.s. "Wandle", a collier engaged on the Tyne-London run. The course having been laid off on the chart, the readings that should be obtained on the red decometer as each green line was crossed were measured off and listed. Steering instructions were attached to the decometers, e.g. 'Port' against a clockwise arrow, and 'Starboard' against a counter-clockwise arrow. Once the ship's head had been set for the particular course, the ship was kept to the course directly from the Decca readings. The red decometer reading was observed as the green pointer indicated zero. If the red reading was in error clockwise, course would be shifted to port, and if counter-clockwise, to starboard. This method is particularly useful in pilotage waters, as immediate indication is given (without the delay of plotting) should the ship deviate from the desired route.

Consistency of Decca fixes at navigational reference points

31. The determination of the absolute accuracy of the Decca system is dealt with above, and is based on a large number of readings at fixed

stations under scientific observation. The measurements made in the course of the operational research trials with merchant ships cannot of course be regarded as a check on the absolute accuracy of the system, firstly because of the uncertainty of the geographic positions of the reference points (usually buoys) and also because the distances and bearings from the reference points are themselves subject to error. Nevertheless it is considered worthwhile to include some diagrams (see Figs. 4) to indicate the degree of consistency of Decca fixes at some reference points. It must be emphasized that the diagrams include the personal errors made by the mariner in judging distance and bearing, but readings when the ship was more than one cable (200 yards - 183 metres) from the buoy have been ignored as likely to be too much in error. The buoys themselves may shift position with the tides. Also, the fixes were taken at random intervals during the six months trial, by different ships, and in the ordinary course of events without any particular precautions to ensure accuracy. The discrepancies at night might be expected to be appreciably greater than in the daytime, because of the skywave effect, but although the standard deviations of fixes of buoy positions are greater at night than in daytime, the ratio is less than that expected theoretically. The reason would seem to be that the variation due to night effect is swamped by the other variable factors.

32. In order to give some idea of the accuracy of fixing as it appears on a chart, it is pointed out that 1 cable (183 metres) on a 1 : 150,000 chart is represented by .05" (1.3 mm). A fix that will give a mariner his position, in a minute, to within .05" (1.3 mm) on a medium scale chart cannot fail to impress him.

33. Due to the fact that only two slave stations were used in the trials there were areas in which the lattice lines from one pair of transmitters were too widely spaced for a good fix. In this case it was found useful to use the other set of lines as Position Lines, obtaining a fix by means of a cross bearing from a D.F. or Consol station, or from the contour of the sea-bed as shown by the echo-sounder. Examples of this use are given later. A useful Position Line was, in fact, obtained by s.s. "Empire Consistence" off the Norwegian coast in daytime at a range of over 500 miles from the transmitters.

34. Possible causes of lane slipping and unsteadiness of pointers.

(i) Interference from ships' radio transmitter. Remarkably little interference has been caused by ships' transmitters. Only once has any effect been noticeable, in spite of the fact that transmitter and aerial are usually

adjacent to the Decca receiver and aerial. The only effect observed has been a slight needle flicker during telegraphy transmissions.

(ii) Noise on ships' mains. On one or two ships while normal performance was obtained from the Decca installation while the ship was within about a hundred and fifty miles of the transmitters, it was observed that lanes were slipped at greater distances. The cause of this was not at first apparent, as the receiver appeared to be in perfect order, and there was no fault in the aerial system, but tests showed that there was considerable noise from ships mains, and this not only interfered with the proper reception of Decca signals, but was responsible for the poor performance of the ships' wireless telegraphy receiver. Lane slipping due to this cause has been eliminated by incorporating a suitable filter as standard equipment in all Decca receivers.

(iii) Generator switching - sudden loads. Lane slipping was observed on one or two ships when the load was switched from one generator to another, or a heavy load placed across the circuit. The sudden impulse caused the decometer needle to rotate the greater part of a revolution, causing a lane to be gained or lost by the time it had come to rest. In certain ships where the electrical installation is unreliable it may be advisable to instal a separate source of power for the Decca set.

(iv) Interference from land Radio Stations. This type of interference has been by far the most serious cause of lane slipping within the recommended distance. A Dutch telegraphy station, operating on the identical frequency as the Decca master station, caused considerable lane slipping on ships passing close to the Dutch and Belgian coasts. For example, the master of the "Plover", sailing from Harlingen (in the Zuider Zee) to London, reported a loss of 4 red lanes and 1 green lane between Harlingen and the Goeree Light Vessel, a distance of 120 miles.

Since this station has shifted frequency the trouble has ceased.

Experience by Ships' Officers

35. All the ships' officers who had used the Decca system for navigation, were in agreement that it represented a very considerable advance on any aid to navigation hitherto generally available to the Merchant Service. Many officers were most emphatic that the system would prove of the greatest value to navigators. Their regard for it was by no means lessened, but was rather increased once the installation ceased to be a novelty. One officer stated that if he were transferred to another ship not fitted with the system, he would feel quite lost without it. These opinions were not confined to officers who had had experience of modern radio aids during the war; Masters who had been at sea for thirty years or more, and who would have been expected to be critical of any innovation of this nature in the art of navigation, were just as interested. Navigators look forward to the time when it will no longer be necessary to remain in swept channels, and they will be able to choose their own course and follow it by Decca fixes.

36. The relationship of the Decca system to radar was also discussed with ships' officers who were asked directly whether they considered that a ship with a radar set on board would find the Decca set superfluous. The opinion was to the contrary; radar and a position finding system were complementary to one another. The Decca Navigator system by itself cannot be used to maximum advantage in conditions of extremely bad visibility, because of the danger of collision. Radar, while being invaluable as a collision-warning device, can only give the ships position when the vessel is within range of land or other known reference points, and there are sea conditions in which difficulty may be experienced in locating buoys. A combination of Decca and Radar, provides all the information that the mariner needs.

37. The following are examples of the uses to which the Decca system was put during the trials period. Although the system has been approved for coastal navigation, it is evident that it has a much wider field of usefulness.

a. Maintaining course in open sea away from sight of land.

This of course is the most obvious use of the system and when the buoyed routes are removed, will become more important. So far it has been used only by ships crossing the North Sea or the English Channel, where the direction of the lanes happens to be convenient for ships to follow one particular lane in

order to reach the buoyed routes to London. Ships crossing the North Sea from Germany can follow a lane for about 100 miles, and be brought up to the Smith's Knoll Lightship off the East Coast of England. Using the 1 : 1,000,000 R.A.F. Chart, the master of m.v. "Channel Coast" found that by following the green lattice line J30, he could make a good course from the Channel Islands past Cape La Hague to the English Coast, and has sailed on this line regularly.

b. <u>Maintaining course when visibility prevents any sea - or land - marks from being seen.</u>

Several instances of this type of use were reported, of which two are quoted. The mast of s.s. "Wandle" reported using the Decca Navigator, in conjunction with the echo-sounder, for navigating in fog from Flamboro' Head to H1 Buoy, about 40 miles, and after sighting the buoy proceeding to London, in moderate visibility. On the return trip, in similar conditions, the Pilot cutter was picked up in its appointed position at the entrance to the Tyne, when other vessels were anchored unable to make the port through the fog. The master of m.v. "Oriole" reported that he had navigated from the South Foreland to Le Havre Light Vessel in thick fog, without sight of any buoy or beacon; and that the final leg of his course, all of which was carried out by Decca readings, had led him straight up to the light-vessel.

The captain of the "Empire Spearhead", a liner employed as a troopship between Hull and Cuxhaven, and which is fitted with radar, sent this report:

> "I would like to bring to your notice, as a matter of interest, two occasions where the Decca proved itself extremely useful and accurate during the passage just completed.
>
> During heavy snow (visibility ¼ mile) the course was altered to make a known positive error on one side of the track,

until the Decca co-ordinate was reached which passed through the position of the buoy. Course was then altered to correspond with the direction of the co-ordinate. In a very short time the buoy was picked up right ahead.

This procedure was again used to pick up a buoy, the light of which was extinguished, and the buoy was found close-to in the darkness. The only weakness, of course, lies in turning the ship across the channel of traffic in thick weather, and without Radar, it would be a bad practice."

It should be pointed out that this was carried out in an area in which a cross fix was not possible, as it was a "blank" area for the red lattice, and the purple decometer was not fitted. On a subsequent voyage, with a Ministry of Transport observer on board, this co-ordination of radar and Decca was again used in similar weather conditions and with the same successful result.

c. <u>Maintaining course along a buoyed route at night, when some of the buoys are extinguished</u>.

It is not uncommon for buoys either to be out of position or their light extinguished, particularly after rough weather, and this may be disconcerting to the mariner who is following a buoyed route at night. Several instances in which Decca was of use on such occasions have been reported. The master of m.v. "Falcon" sent in this report:

"At night in a rough sea, vessel in ballast, an unexpected buoy was observed flashing every five seconds. No such light being expected, and ship only just coming on to the Decca chart, there was doubt as to position. Decca established position, found correct by subsequent bearings off Dungeness after course was altered. The buoy was P.B.2, flashing incorrectly.

Outward bound for Havre, steering for buoy D.B.3, the buoy was not sighted. At Decca position for D.B.3, course was altered for next buoy. D.B.3 was then sighted close alongside (within feet) with its light extinguished."

d. <u>Allowance for the set of tidal streams</u>

Even when weather conditions are ideal, and the ships position is in no doubt, the Decca Navigator can still render good service by giving an immediate and continuous record of the amount by which the ship is being set by tidal streams, so that the course and speed may be adjusted accordingly. This facility was used particularly on the Dover Calais run by the "Royal Daffodil" who (as previously mentioned) maintained a continuous record of her course across the channel so as to correct her course as soon as any deviation was observed. It is in fact this correction of the setting of a ship by tidal streams, and by wind, and the resultant saving in time, which makes the Decca Navigator valuable on even short runs.

e. <u>Use for pilotage at short range</u>

In the Thames Estuary, the accuracy of the Decca system is very high. The m.v. "Goldfinch" was successfully navigated in fog, visibility 25 yards, through the difficult Princes Channel in the Thames Estuary, right up the Thames as far as Thames Haven through a 300-yards wide channel, mainly by Decca readings. Decca charts were not available for any of the higher reaches of the river, otherwise the ship would have continued further.

f. <u>Anchoring in a safe position in fog.</u>

The occasion may arise when it is advisable to anchor in a position well clear of the shipping channel. s.s. "Cormorant" reports that in dense fog in the Thames, the ship was anchored in a position indicated by the Decca Navigator as being to the north of the shipping channel. Upon the fog clearing, the position was exactly confirmed.

g. <u>Cable-laying, (especially when out of sight of land), and Location of a particular reference point at sea (e.g. a broken cable)</u>

These special applications of the Decca Navigator are the subject of a report by the master of H.M.T.S. "Iris", a cable ship operating from Dover, on the occasion of a repair to the Anglo-Dutch No. 4 Cable, No Decca chart of the area was available at the time, and it was therefore necessary to make a special one. The report states that the ship was at sea before information was available to make a chart, and continues:-

"When the Decca co-ordinates were received on the evening of the first day they were plotted on the grappling sheet and an appropriate Decca lattice was constructed from the information provided - zone and lane number, width and direction of the lane. It was then found that the cable was half a mile to the southward of its charted position.

Subsequent grappling for the Dutch end of the cable on the following day was plotted by visual fixes from the Mark buoy, but grappling could quite easily have been undertaken without a mark buoy, the plot being kept by the Decca alone.

When laying in the insertion, one mile in length, a plot of the track was kept by visual fixes from the mark buoy in the usual way, but the lay was controlled entirely by Decca. It happened that the Decca Red Lane was parallel to the track of the cable so that a deviation of ten yards to port or starboard of the line was immediately indicated on the Red Decometer and appropriate helm action could be taken at once to maintain the course. A table was drawn up beforehand showing the distance along the far cable buoy at each crossing of the appropriate Red Lane along which the lay was being made by every tenth part of a green lane. The

distance off the cable buoy at any time was thus readily ascertained.

In order to test the reaction by visual fixes, the ship was allowed to drift up to fifty yards off the track by the red decemeter before counteracting the set. The visual plot confirmed the track made by the Decca Navigator. The lay was made across a two knot tide.

It so happened that this was an ideal example of the use of the equipment, but as experience is gained more ways of making use of the Decca Navigator become apparent. It is again stressed that only by the provision of the appropriate lattice charts can full advantage be taken of this remarkable aid to navigation."

In a later report dealing with repairs to another cable an account was given of the use of Decca and Radar in conjunction. The Master emphasises that without these two aids it would not have been possible to begin work because of weather conditions. "Not less than 3 days have been saved on the repair, thereby reducing the expense considerably and restoring an important cable to service 3 days before it could normally have been possible."

h. Maintenance of Buoys

A report was received from the master of the Trinity House Vessel "Alert", responsible for the maintenance of buoys at the approaches to London. The officer-in-charge cites these four examples, after making a general statement.

"On 26/11/46 "Alert" was detailed to relight South Goodwin No. 2 Gas Buoy. It was not possible to arrive at the casualty before dark. Assisted by 'Decca', "Alert" was navigated to within searchlight range. The buoy was located and relighted.

With only dead reckoning aids, night work in this area of strong cross tides and shipping would be neither prudent nor practicable. The tending steamer would

have been compelled to await daylight, by which time the weather had broken and the operation could not have been attempted for yet another 24 hours.

As it was "Alert" was able to relight the buoy at the earliest possible moment, thereby reducing risk of damage to the buoy or passing ships through collision and was then free to carry on with other work as ordered.

On 12/12/46 assisted by Decca, "Alert" located and relighted 53B Searched Channel Gas Buoy before dawn during a storm lull. Having got away with this early start it was then possible to utilize to the full one of the shortest days of the year. Nine gas buoys were lifted and 130 miles were steamed in so doing.

"Alert" was detailed to replace the missing H.F.P. Whistling Gas Buoy, at South Shingles on 11/12/46. The AP was found before dawn by incorporating Decca and dead reckoning, and the buoy got ready overboard for laying. At first light the Decca position was checked and found correct by angles and the buoy was laid. Half an hour later the weather was unfit for the operation.

On 6/12/46 PBI Gas Buoy (Dover Straits) was missing from station. Notwithstanding a strong cross tide and considerable traffic, "Alert" aided by Decca carried out an organised search with a thoroughness, speed and efficiency not possible with dead reckoning alone.

The above four incidents are not isolated examples of Decca co-ordination, in fact there are very few working days when it cannot be used to expedite operations."

i. Survey work in areas close to the transmitters.

The Decca Navigator has been used for survey work by H.M.S. "Franklin" a survey vessel carrying out work for the Hydrographer of the Navy. The method used in order to obtain the highest degree of accuracy, is to keep one set in a fixed position as a local monitor, while a second set is employed in the motor boat used for the actual survey. In this manner temporal variations can be eliminated by providing communication between the operators of the two sets and applying any variations noticed at the fixed station to the mobile one. A few extracts from the Commanding Officer's report are given.

> "24th July 1946. During the forenoon the sweep over the 14 foot wreck was completed. The positions of fouling have been plotted from the observations taken this day, corrected for Monitor station readings. After this, the wreck passed over on Fix No. 25 of 23rd July was re-located easily using only Decca. The Green and Red values were the same plot as before when the ship was over the wreck. This was the most convincing test yet done, as the visibility was so poor that no marks could be seen except the floating beacon "Tites" and there was no swirl from the wreck visible.
>
> It is considered to be quite invaluable for surveying.....its accuracy on scales of 175,000 and smaller, is as great or greater than that obtained from normal sextant and Station Pointer fixing on floating beacons, when visibility conditions, human errors and plotting errors are taken into account."

j. Correcting for compass errors

It may happen that a vessel has to put to sea with a cargo which appreciably affects the magnetic compass, and no gyro-compass is fitted. Such a case was reported by the master of s.s. "Elysian Coast" which was loaded with a cargo

of phosphates contained in steel drums. These drums produced such a deviation of the compass that it was found extremely difficult to keep the ship in the buoyed channel. Steering into the sun, with a low haze over the water, enhanced the difficulty of finding the buoys. In the circumstances, the positions given by the Decca navigator were invaluable.

k. Pilotage in an emergency

The s.s. "Cormorant" reported that on one voyage from London to Antwerp, the weather was so bad that the pilot boat was not at its station at N.F. 9 buoy. (This buoy is at the beginning of a route through mined waters with numerous wrecks scattered about). The course from this buoy was therefore carried out using the Decca Navigator in conjunction with the lattice chart of the Scheldt Estuary. The return journey was made under similar conditions, the Decca Navigator being of the greatest assistance.

Ships' officers also pointed out other possible occasions on which the Decca Navigator would be likely to be of use. Two such are, for observing whether a ship is dragging its anchor (the movement of an anchored ship as the tide turns is often observed), and for giving position to rescue vessels, should a ship break down at sea.

Lane Identification

38. The Decca Navigator System as at present in service is operating without any form of lane identification. This was also the position during the marine trials. Experience has shown that, contrary to early expectations, the System provides for the purpose of coastal and short sea trading an extremely useful navigational aid service without the facility of lane identification, providing the user is aware of the limitation of the System and exercises certain simple precautions. However, it is quite certain that for the System to be generally employed for the purposes of marine navigation and to meet the most stringent operational requirements, lane identification is an ultimate necessity. It is, therefore, generally agreed that while the System can certainly be employed for an interim period without this facility, it is necessary to show that it is capable of solution in order that its general adoption may be considered as definite.

39. As a result of a comprehensive investigation of the whole problem and a careful examination of all alternative methods, the Decca Navigator Company have now presented their recommended system, the principle of which has been satisfactorily demonstrated under seagoing conditions using the experimental stations on the south coast of England.

40. The system demonstrated provides complete resolution within a Decca Zone, that is within an angle which is never less than 12°. This is adequate for marine navigation.

41. Subsequently as a result of scientific tests it has been decided to incorporate a vernier pointer which, operating as an integral part of the lane identification meter, provides a fine reading which has an accuracy six times that of the basic identification. Further scientific tests are being carried out to determine the maximum range of the lane identification system, but the tests have already shown that it is accurate within a distance of the same order as the night range of the main transmissions, i.e. 240 nautical miles.

42. The following briefly describes the method of lane identification.

42. 1. The Lane Identification meter is shown at the top of Figure 7. It will be seen that it has three scales and these are engraved on perspex rings individually illuminated in the colour corresponding to the meter or pattern to which they refer, i.e. Red, Green, Purple. This meter operates only when identification signals are being transmitted. Only one identification takes place at a time, and the other two patterns are temporarily shut down while this identification is in progress. The time taken is sufficiently short to avoid any risk of "lane slipping" on the meters associated with the patterns which are removed. It is intended that the lane identification transmissions will be made at frequent intervals, and a possible time schedule is

8:00 - Red,	8:01 - Green,	8:02 - Purple
8:05 - Red,	8:06 - Green,	8:07 - Purple
8:10 - Red,	8:11 - Green,	8:12 - Purple, etc.

42. 2. When an identification transmission takes place, the appropriate scale of the identification meter lights up and the main pointer swings to the correct position on that scale. For example, at 8:00 the middle scale will light up and the pointer will swing to the position to which the units pointer on the red meter should be set.

42. 3. It is seen, therefore, that this identification is completely automatic and requires no operation on the part of the user except to read off the correct lane number when the meter is illuminated. It reduces the ambiguity of the system to that of a 14.2 Kc/s pattern (in the case of the red pattern a reduction of 24 to 1). It assumes that the Navigator has some prior knowledge of his position so that he knows within which zone (zone width approx. 12^o azimuth), he is situated.

42. 4. It will be noted that in addition to the main pointer on the Lane Identification meter there are six light pointers. These six pointers are all fixed to a common shaft and during the identification transmission serve as a vernier indication. During daylight the vernier pointers may be disregarded as the agreement between the main and vernier pointers will be good. At night the difference between the main and vernier pointers will increase with range, and beyond 100 miles there will generally be a difference in indication; under such conditions the correct lane reading is that indicated by the fine pointer nearest the main pointer.

42. 5. The vernier pointers, which have six times the ambiguity of the main identification pointer, also have six times the accuracy. The main pointer, is used, therefore, to remove the ambiguity of the fine pointers by indicating which one to read.

43. Final engineering of the System is now in hand, and it is the intention of the Decca Navigator Company to introduce the System into general service at the end of 1947. Figure 8. shows the System in general schematic form.

CONCLUSION.

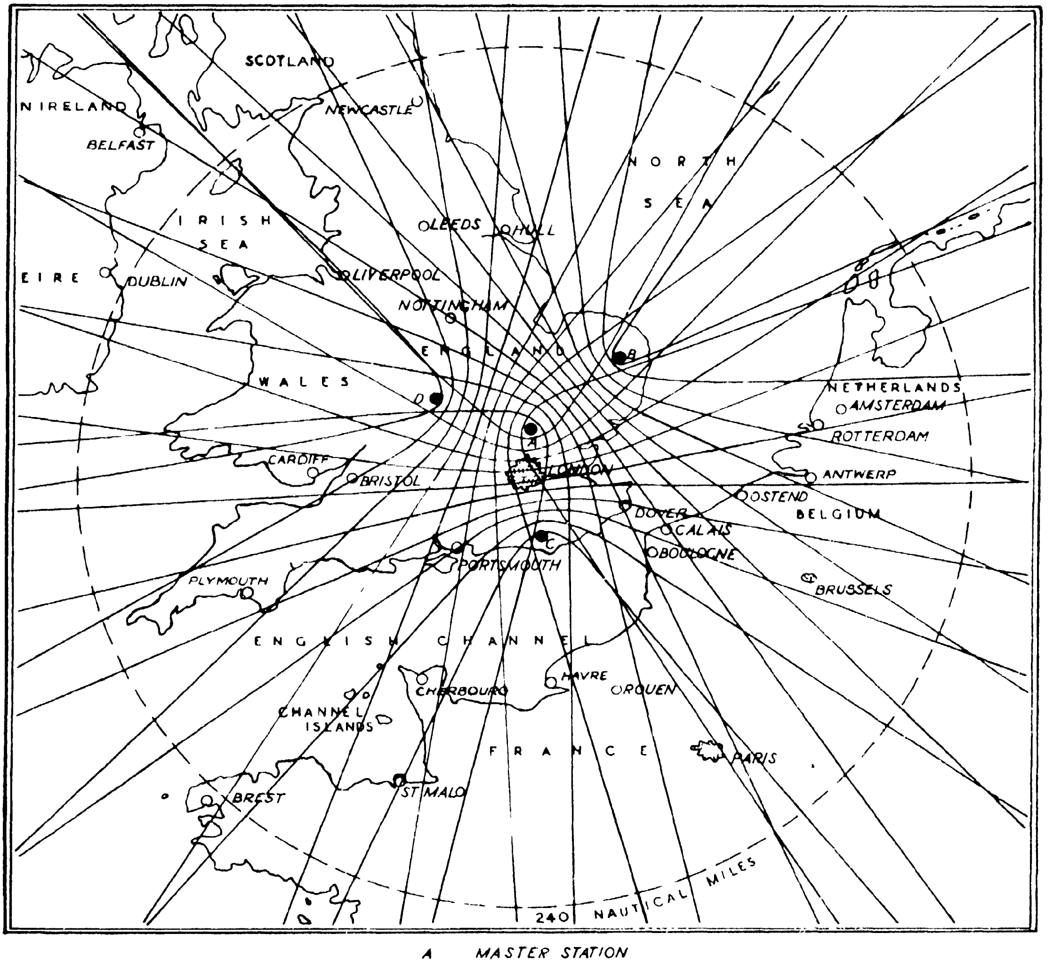
The trials carried out show the Decca system, even without lane identification, to be a simple, rapid and accurate position fixing system within 240 nautical miles of the centre of a chain of stations, which will increase the safety of life at sea, and by its many applications will justify itself economically.

The development of a method of lane identification makes possible the wide adoption of the Decca system in all types of ships.

FIGURE I.

MAP SHOWING THE LATTICE ZONES & SERVICE AREA FOR COASTAL NAVIGATION OF THE ENGLISH CHAIN OF THE DECCA NAVIGATOR SYSTEM

ZONES ARE APPROXIMATE ONLY



A MASTER STATION

B RED SLAVE

C GREEN SLAVE

D PURPLE SLAVE

NAUTICAL MILES

50 0 50 100 150

100 0 100 200 300

KILOMETRES

PGG MOT

FIG. 2. MAP SHOWING PRINCIPAL ROUTES FOLLOWED BY SHIPS DURING DECCA NAVIGATOR TRIALS AUGUST 1946 TO JAN. 1947.

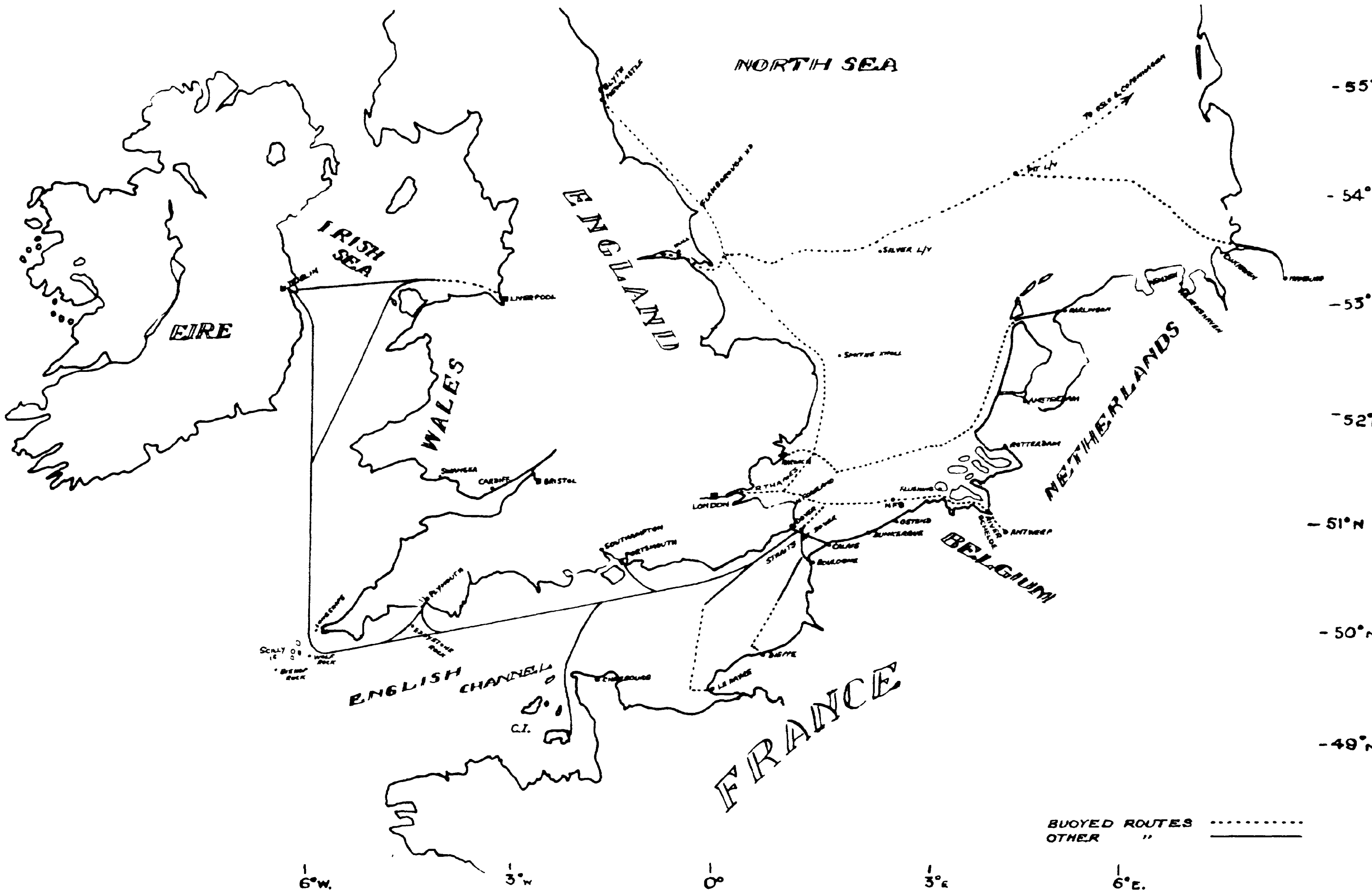


FIGURE 3. MAP SHOWING CHARTS OVERPRINTED WITH DECCA LATTICE AND USED DURING DECCA NAVIGATOR TRIALS AUGUST 1946 TO JANUARY 1947

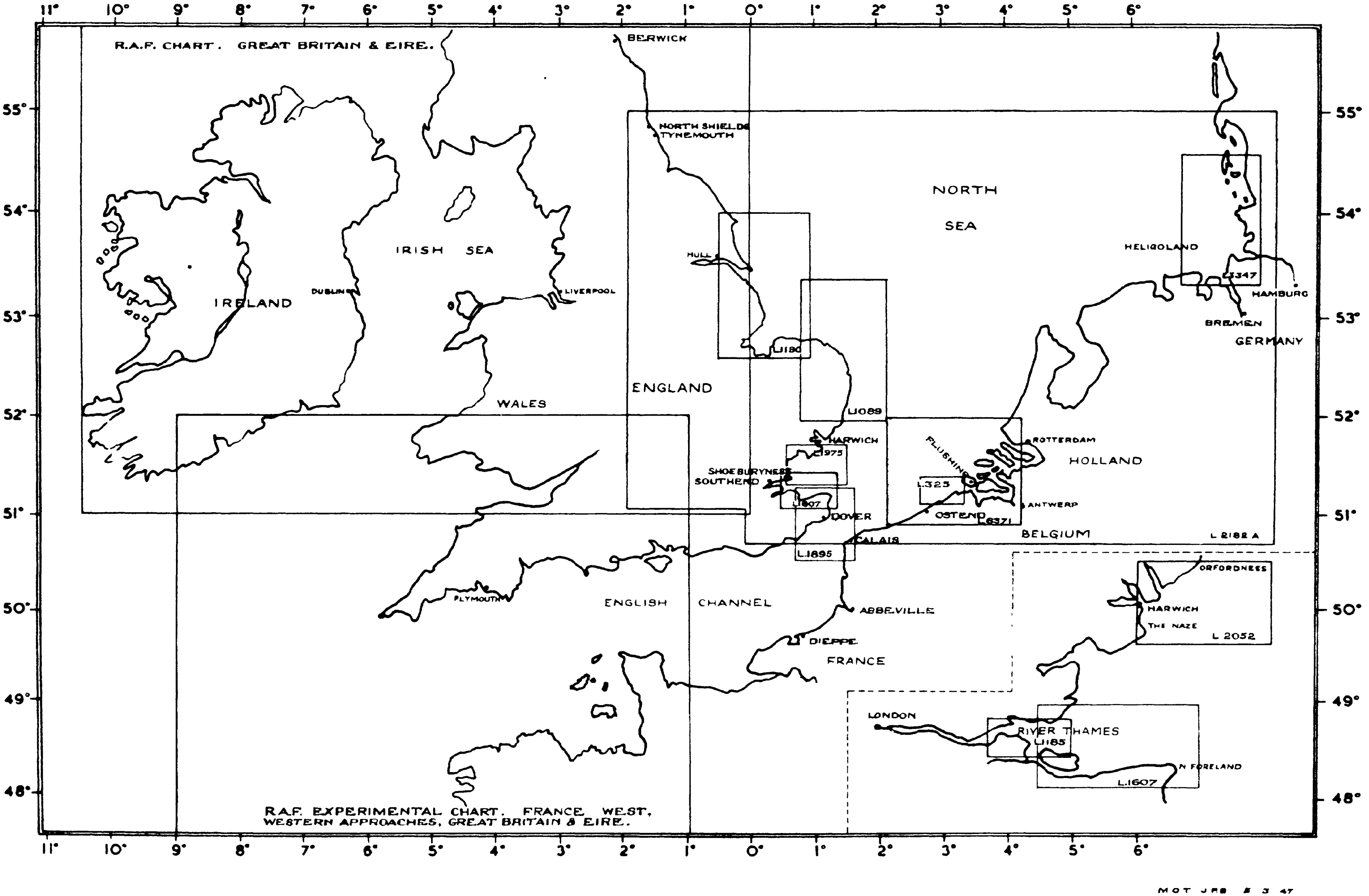
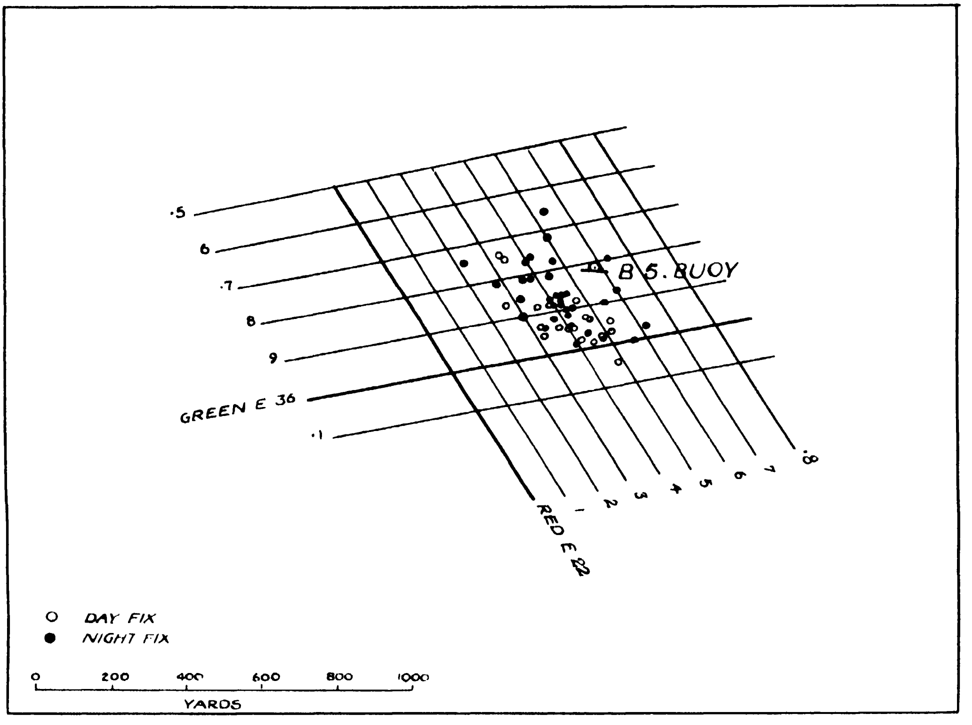


FIG. 4. (a)

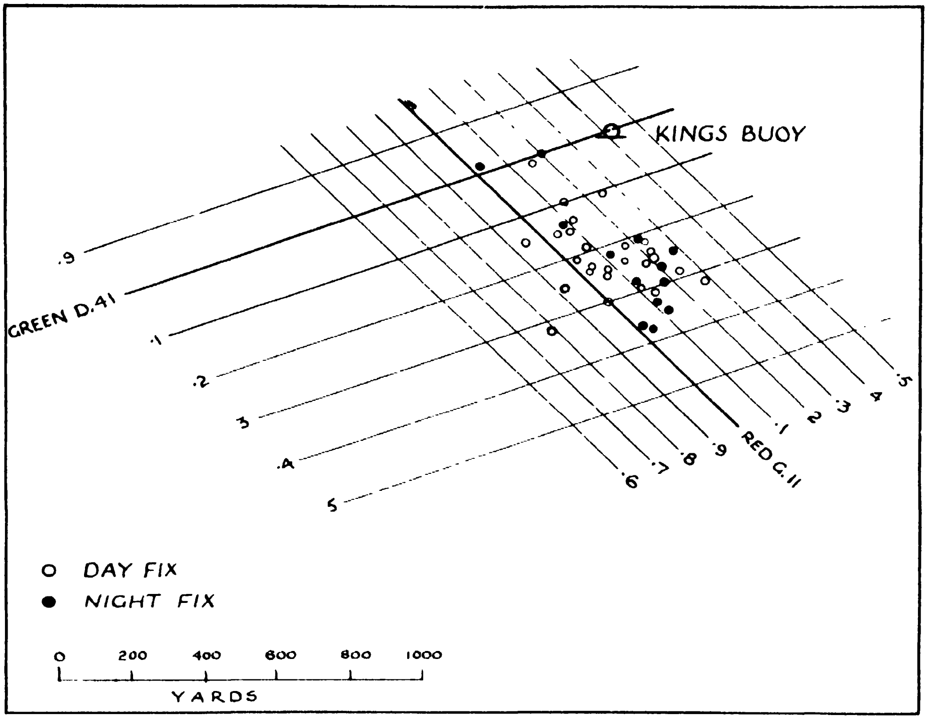


DISTRIBUTION OF FIXES AT B 5 BUOY

48 NAUTICAL MILES FROM MASTER STATION. (89 k M.)

			DAY	NIGHT
R M S RADIAL DISTANCE ABOUT MEAN POSITION		(YARDS)	110	150
STANDARD DEVIATION	(RED LATTICE)	(LANES)	0 070	0·097
" "	(GREEN LATTICE)	(LANES)	0 063	0 086

FIG. 4 (b)

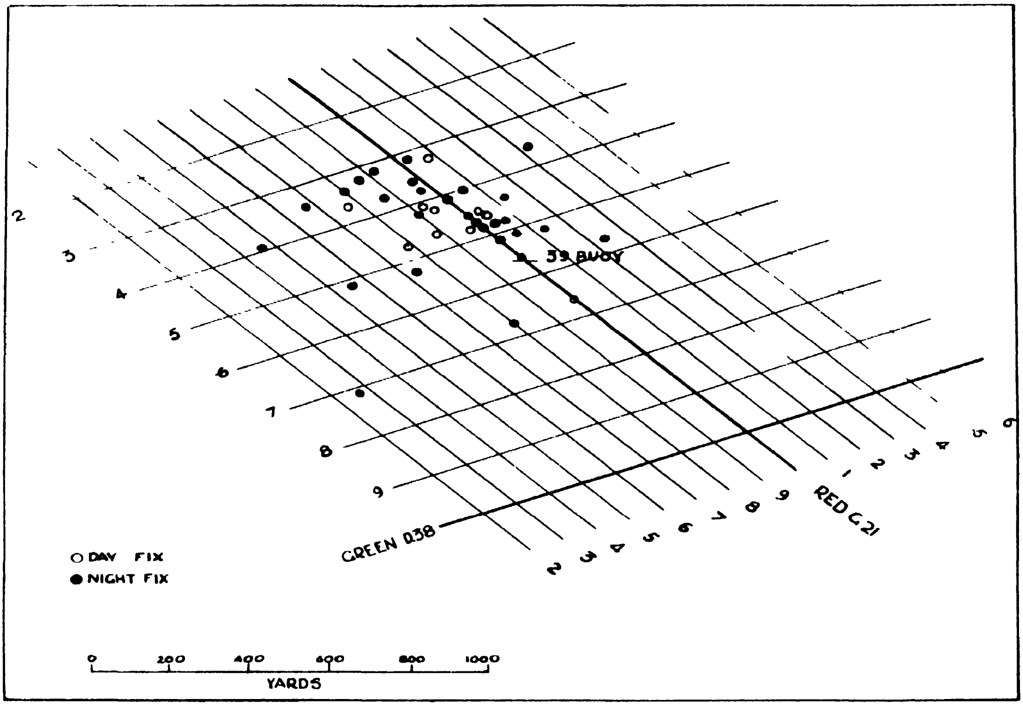


DISTRIBUTION OF FIXES AT KINGS BUOY.

57 NAUTICAL MILES FROM MASTER STATION. (106 KM.)

		DAY	NIGHT
R.M.S. RADIAL DISTANCE ABOUT MEAN POSITION	(YARDS)	150	220
STANDARD DEVIATION (RED LATTICE)	(LANES)	0·112	0·081
" " (GREEN LATTICE)	(LANES)	0·074	0·128

FIG.4 (c)

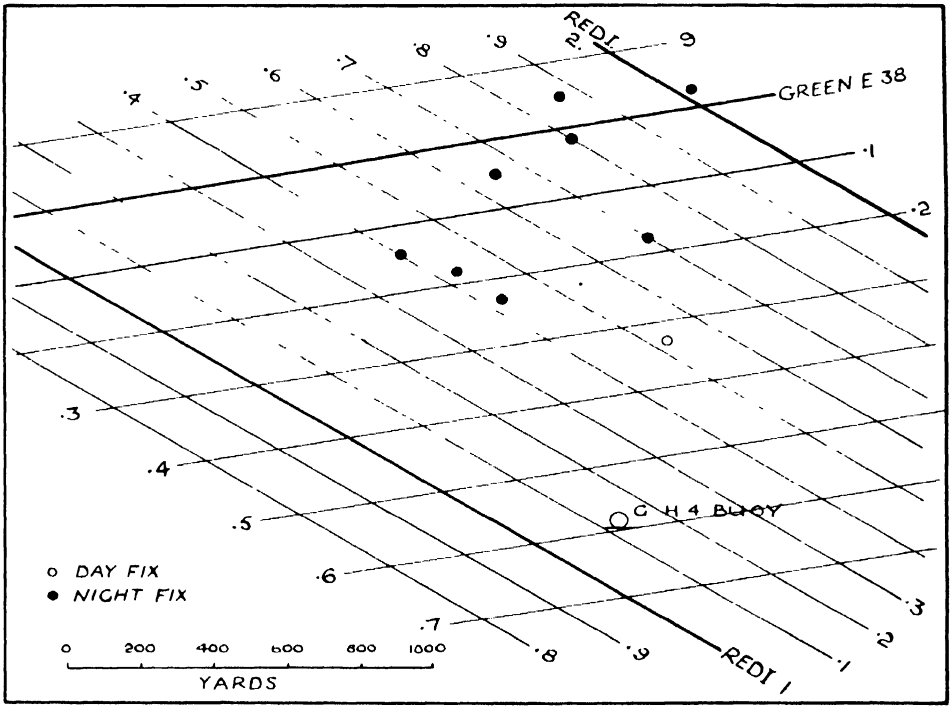


DISTRIBUTION OF FIXES AT 39 BUOY, 59 NAUTICAL MILES FROM MASTER STATION. (109 KM)

			DAY	NIGHT
R M S RADIAL DISTANCE	ABOUT MEAN POSITION	(YARDS)	155 ·	265
STANDARD DEVIATION	(RED LATTICE)	(LANES)	0·101	0 238
" "	(GREEN LATTICE)	(LANES)	0·074	0 101

CDC MCT NF 27 2 47

FIG. 4(d)



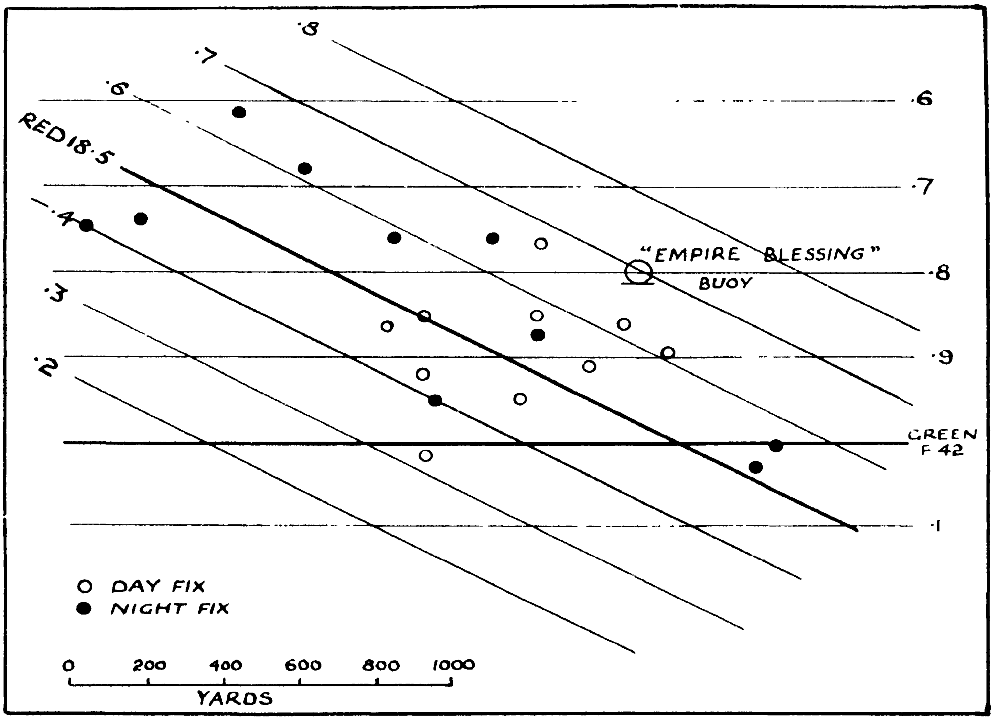
DISTRIBUTION OF FIXES AT GH 4 BUOY.

92 NAUTICAL MILES FROM MASTER STATION. (170 K M).

		DAY	NIGHT
R M S RADIAL DISTANCE ABOUT MEAN POSITION	(YARDS)	-	460
STANDARD DEVIATION (RED LATTICE)	(LANES)	-	0 254
" " (GREEN LATTICE)	(LANES)	-	0 161

C D O, MOT. LDN.3 347

FIG. 4 (e)

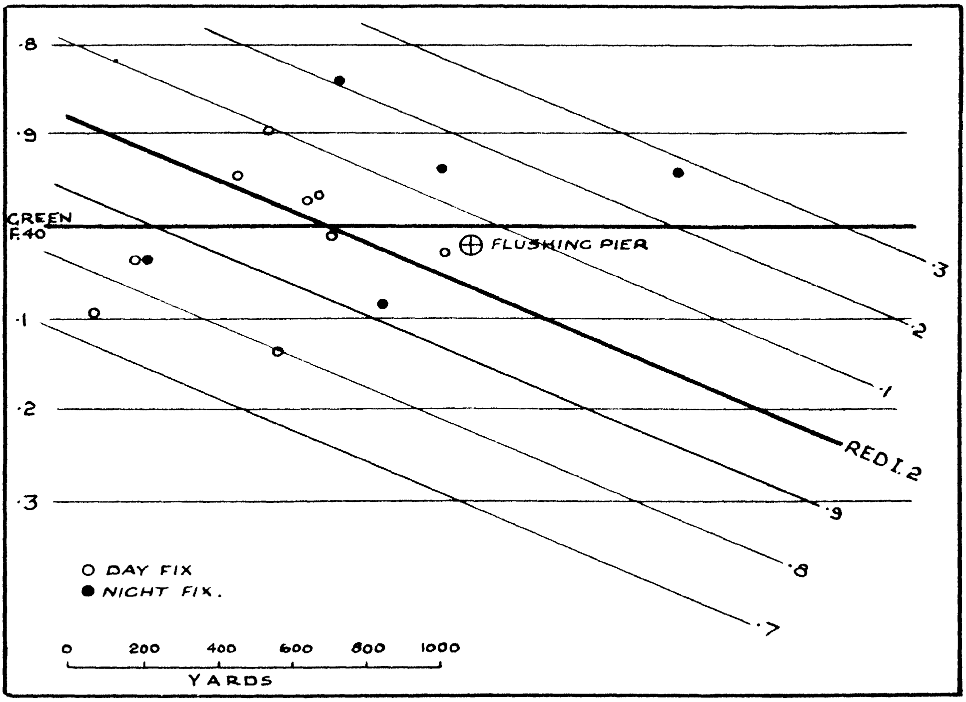


DISTRIBUTION OF FIXES AT "EMPIRE BLESSING" BUOY

126 NAUTICAL MILES FROM MASTER STATION. (234 K M.)

		DAY	NIGHT
R.M.S. RADIAL DISTANCE ABOUT MEAN POSITION	(YARDS)	288	624
STANDARD DEVIATION (RED LATTICE)	(LANES)	0·098	0·089
" " (GREEN LATTICE.	(LANES)	0 062	0·131

FIG. 4. (f)



DISTRIBUTION OF FIXES AT FLUSHING PIER.

138 NAUTICAL MILES FROM MASTER STATION. (256 k.M.)

		DAY	NIGHT
R.M.S. RADIAL DISTANCE ABOUT MEAN POSITION	(YARDS)	342	560
STANDARD DEVIATION (RED LATTICE)	(LANES)	0·113	0·167
" " (GREEN LATTICE)	(LANES)	0·069	0·075

C.D.O. M.O.T. L.D.W. 27.2.47

*

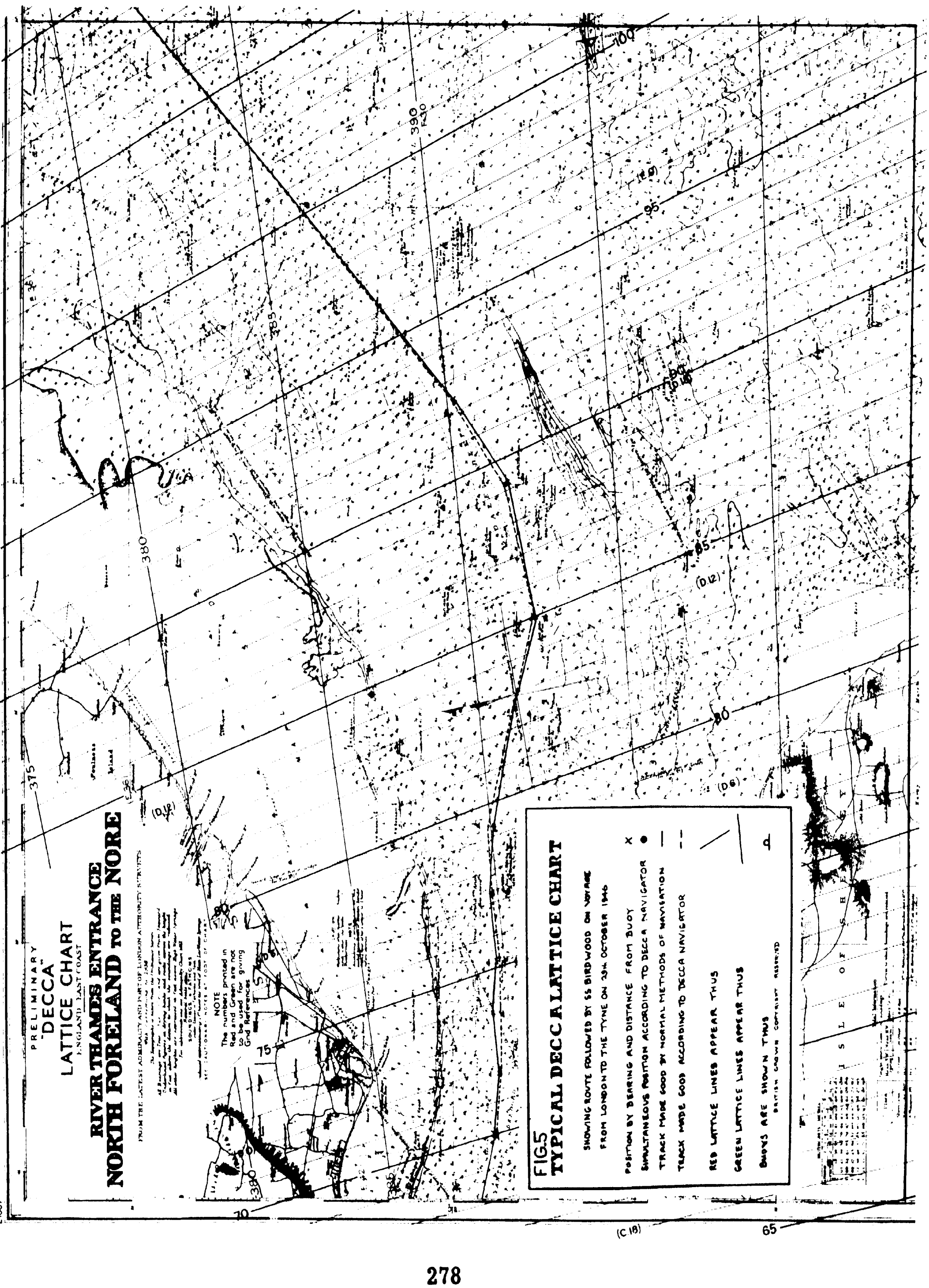
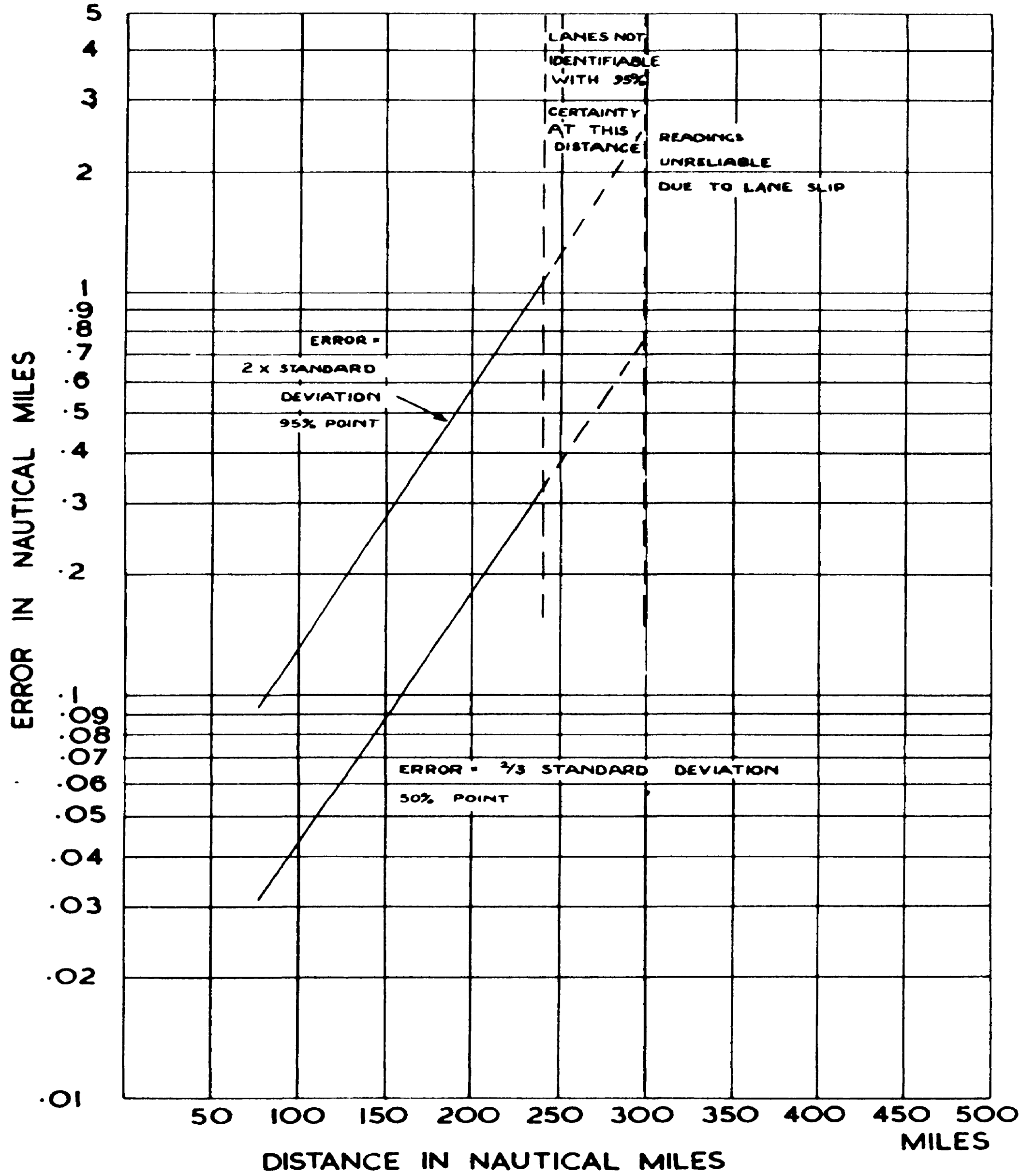

PRELIMINARY
"DECCA"
LATTICE CHART
ENGLAND EAST COAST
RIVER THAMES ENTRANCE
NORTH FORELAND TO THE NORE
NOTE
The numbers printed in Red and Green are not to be used for giving Grid References
FIG.5
TYPICAL DECCA LATTICE CHART
SHOWING ROUTE FOLLOWED BY SS BIRDWOOD ON VOYAGE
FROM LONDON TO THE TYNE ON 23rd OCTOBER 1946
POSITION BY BEARING AND DISTANCE FROM BUOY
SIMULTANEOUS POSITION ACCORDING TO DECCA NAVIGATOR
TRACK MADE GOOD BY NORMAL METHODS OF NAVIGATION
TRACK MADE GOOD ACCORDING TO DECCA NAVIGATOR
RED LATTICE LINES APPEAR THUS
GREEN LATTICE LINES APPEAR THUS
BUOYS ARE SHOWN THUS
BRITISH CROWN COPYRIGHT RESERVED
110
(E.12)
105
(E.6)
100
(E.0)
95
90
(D.18)
85
375
380
385
390
100
95
90
85
80
75
70
65
(C.18)
(D.12)
(D.6)

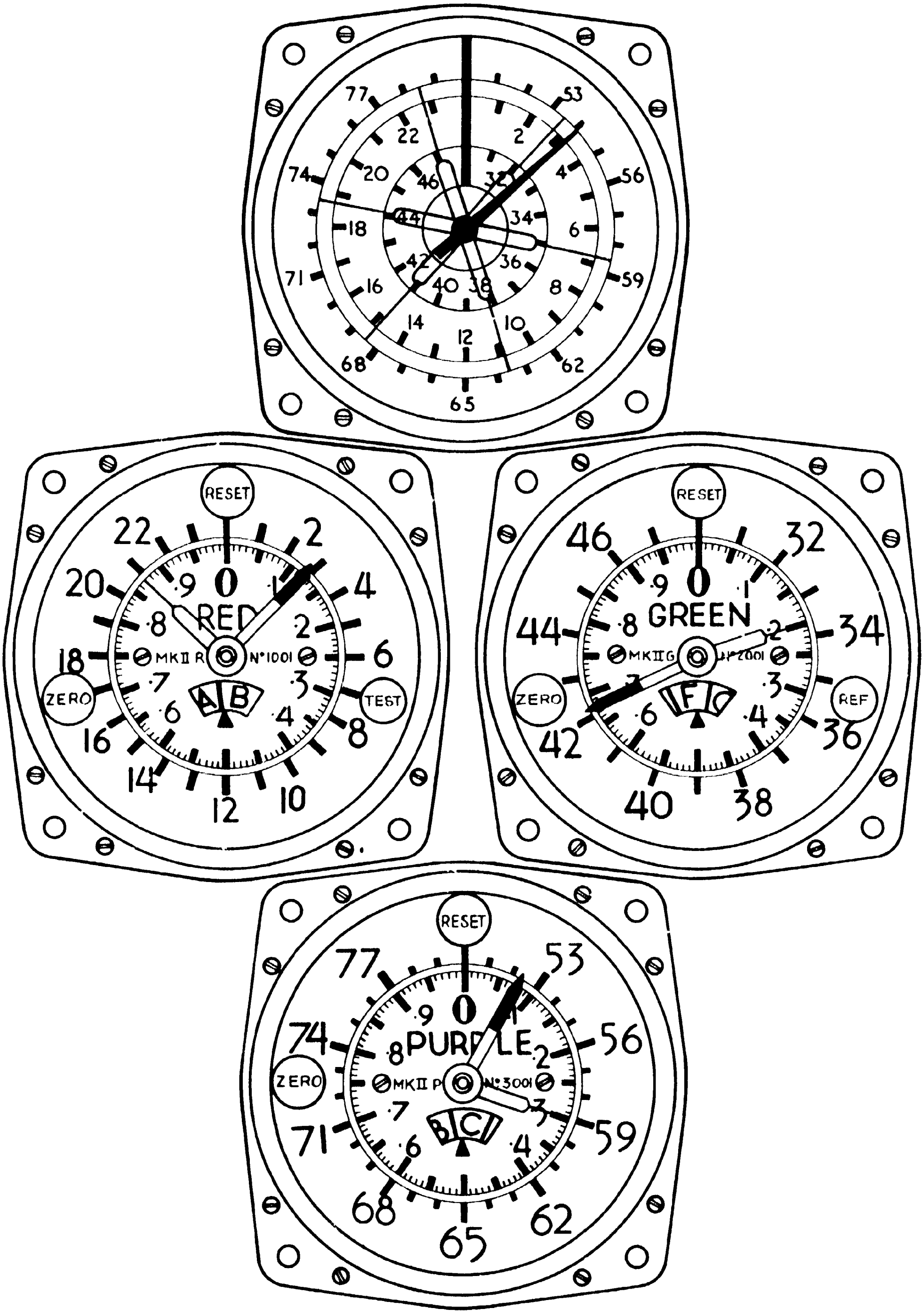
FIG. 6

GRAPH OF DECCA NAVIGATOR POSITION LINE ERROR WITH INCREASING DISTANCE, CLOSE TO CENTRE OF COVER (WINTER NIGHT CONDITIONS.)



BASED ON MEASUREMENTS MADE BY THE ADMIRALTY SIGNAL ESTABLISHMENT DURING THE PERIOD NOV. 26th — DEC. 2nd 1945 IN AN INVESTIGATION ON THE ERRORS DUE TO REFLECTION FROM THE IONOSPHERE AT NIGHT.

FIG. 7

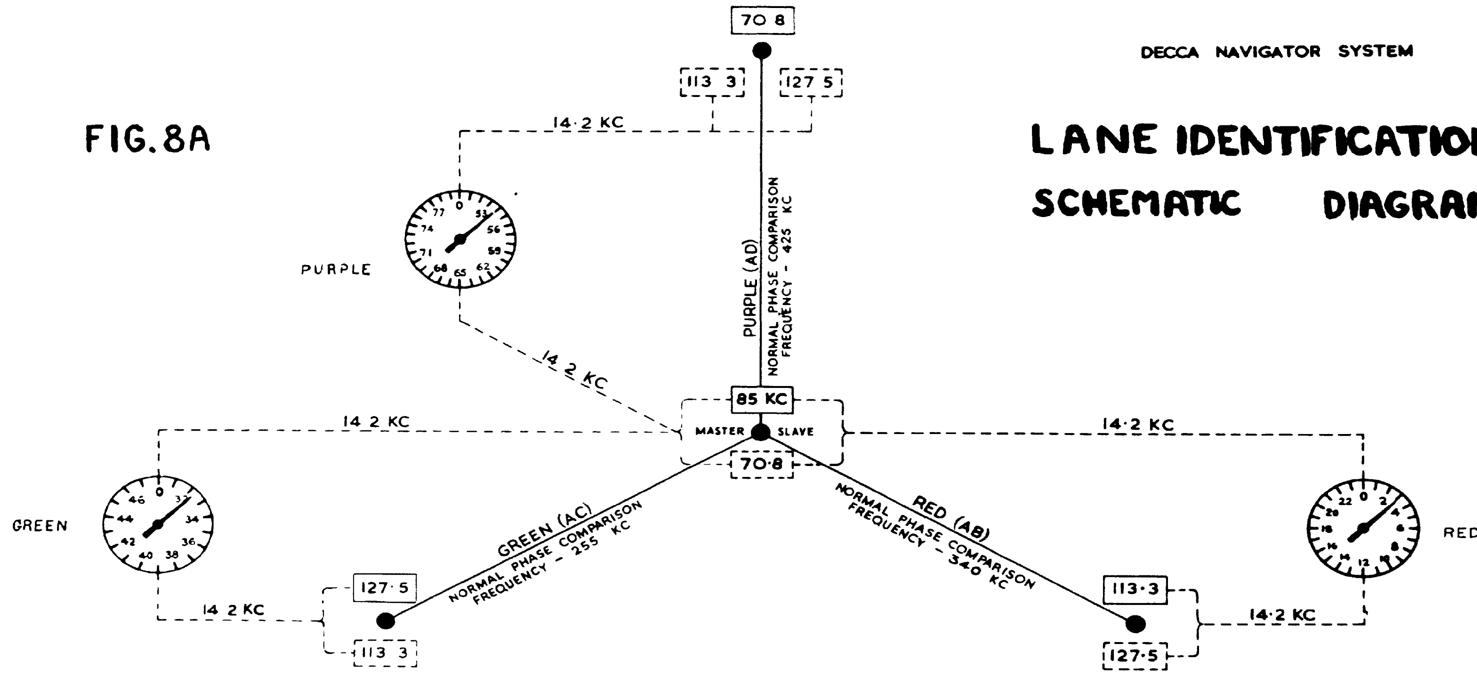


(TOP) LANE IDENTIFICATION METER
(BELOW) RED GREEN AND PURPLE DECOMETERS

DECCA NAVIGATOR SYSTEM

LANE IDENTIFICATION SCHEMATIC DIAGRAM

FIG. 8A



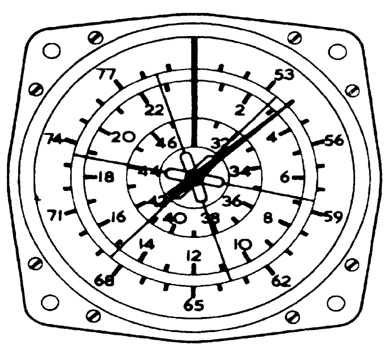
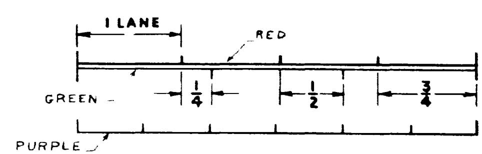


FIG. 8B

LANE IDENTIFICATION METER

OUTER	SCALE	PURPLE
MIDDLE	SCALE	RED
INNER	SCALE	GREEN

ADVANCE OF ONE RED LANE PRODUCES A DIFFERENCE OF ¼ REVOLUTION BETWEEN METERS



VERNIER IDENTIFICATION GROUP

FIG. 8C

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN · · · APRIL 28-MAY 9, 1947

PULSE NAVIGATION SYSTEMS

- By -

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Great Neck, New York

ABSTRACT

A variety of systems for navigation based on pulsed radio transmission have developed during and since World War II. In this paper a brief review of pulse navigation systems is presented, together with a discussion of the most significant scientific and engineering factors that influence the suitability of such systems for practical adoption.

PULSE NAVIGATION SYSTEMS

Basic Ideas

1. The basis of all so-called "pulse navigation systems" is the <u>time</u> required for a pulse of radio frequency energy to traverse a given distance. This principle is utilized for navigation and position finding in three general methods.†

2. In the first method, which will be called the "circular" method, a train of pulses of radio energy is radiated by a transmitter at the unknown position. Some of this energy is returned from a reflecting object or from a radar transponder at a known position, and the time for the round trip is measured. The distance between the points of transmission and reflection is in the simple case directly proportional to the time required for the round trip. To determine the unknown position, the distances to two known reference points are measured, and position is found as the intersection of two circles, drawn on a conventional chart with centers at the two points of reflection and with radii equal to the two respective measured distances.

3. In the second method, which is nothing more than conventional radar, the pulses are radiated in a narrow beam, by means of a directive antenna, and the unknown position relative to the reflecting object is determined from the bearing of the beam and the indicated distance. The first method may also be carried out with conventional radar, although it may be separately instrumented also.

4. The third method of determining position by radio pulses will be termed the "hyperbolic" method. In it, pulses are radiated simultaneously* from transmitters at two known ground positions and are received by equipment at the unknown position. When the unknown position is closer to one transmitter than to the other, the pulses from the nearer transmitter are of course received before those from the more distant one. A comparison of the two received pulse trains gives the time difference of arrival, which is proportional to the difference in distances to the two known positions. A curve may be drawn on the chart of the region such that every point on the curve is closer to the one transmitter location than to that of the other by the same measured amount. This curve is a line of position characterized by the measured time difference. The receiver lies somewhere on this curve. A similar measurement from another pair of transmitters, one of which may coincide with one of the first pair, determines a second line of position and its intersection with the first fixes the

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*In actual systems, the pulse train from one station, the "slave", has a constant delay with respect to the pulse train from the other, or "master" station.

†A fourth method, using two bearings, will not be discussed here.

geographic position of the receiver. Geometrically the lines of position form hyperbolic curves having the two known transmitter locations as focii. Each transmitter pair establishes a family of hyperbolic curves which may be plotted on the chart and used for navigation in a manner quite similar to curves of latitude and longitude. Naturally, positions in terms of latitude and longitude may be readily determined from the chart also.

5. It might appear that circular and straight radar methods provide a simpler procedure for the navigator, because it might seem that ship's own position may be plotted readily on a conventional chart, whereas hyperbolic methods require special charts or more elaborate computation. This is not the case in practice, however, for two reasons. Firstly, it is not an altogether simple matter accurately to plot large distances on charts because the curvature of the earth must be taken into account. Secondly, the work of making the hyperbolic charts, although great, has already been done for most of the regions covered and once done reduces the determination of an individual fix by a navigator to a very simple matter indeed.

6. Of the three methods of electronic navigation, the hyperbolic method alone has the feature that the ship radiates no transmissions and operates entirely as a silent listener with only a receiver for equipment. Although cooperation between the ground stations is necessary, their radiations go out like light from light-houses to be used independently and without interference by all who are within range. This is an important feature, for there is no practical limit or saturation to the service that can be rendered, as in the case with other methods. In the circular methods, mutual interference is generally expected to place a limit of ten to twenty simultaneous users of a given system and region.

7. It is interesting to note that, except for conventional radar, a minimum of three transmitting stations are always required to determine a position fix. In the circular systems, at least two land stations and one ship station are necessary. In the hyperbolic systems at least three land-based transmitters are required and only a receiver is needed aboard ship.

8. An important practical aspect of electronic navigation systems results from the fact that their reference points are terrestrial, and therefore observations make no use of siderial time information and are independent of it. It is thus a simple matter in most systems, particularly hyperbolic ones, to preset the adjustments of the equipment to correspond to a desired future position and to use the indication of error as an aid to steering or to set the course in a predetermined manner. As the desired future position is approached, no matter what the speed or time of day, the observations will get closer and closer to those preset in the equipment, finally coinciding upon arrival at the specified position.

USEFUL DISTANCE

9. Of greatest importance in any consideration of electronic navigational aids is the maximum distance or coverage that may be provided by the system under practical operating conditions. Although the determination of maximum distance for a particular system can only be found accurately from operating field experience in which the effect of field and shipboard maintenance and operation of all parts of the system are inherently included, general trends and approximate values may be obtained from a study of the individual factors. These factors involve well known facts and principles of wave propagation and electrical communication, but they are nevertheless worth some elaboration here as applied to pulse navigation systems.

10. Radio energy may be transmitted from one point on the earth's surface to another, depending on the carrier frequency, the power and the distance, by one or more types of waves or over one or more separate paths, as follows: (1) the "direct wave", which occurs mostly with microwaves and corresponds to the ray of a searchlight; (2) the "ground wave", which is a wave slidingly attached to the earth's surface; and (3) the "sky wave", which is a wave that is bent by the ionized layer or ionosphere and returned to the earth via the sky with one or more successive reflections between earth and ionosphere.

11. Conventional radar operates almost exclusively by means of direct waves, as do certain other navigational systems, and they are thus limited substantially to line-of-sight distances. This limitation is fully compatible with the application to impending-collision warning, inshore, coastal, lake, and river navigation, and harbor traffic control, and it is mainly in this short distance application that radar per se will find use. Direct wave propagation at microwavelengths is affected by certain atmospheric conditions, such as snow, sleet, and heavy rain, the influence being greater for the very short wave lengths. It is, in fact possible to locate storm and hurricane centers with radar. Experience thus far has nevertheless shown that marine radar can see through bad weather of all kinds with adequate vision for short distance navigation.

12. Ground wave transmission is employed in the Loran systems, which are well designed to take advantage of the reliability of this mode of propagation (Loran may also operate with sky waves). The rate at which the strength of ground waves are reduced with distance depends on the electromagnetic characteristics of the earth, in our case sea water, lake or river water, the spreading of the energy over an ever-increasing volume in its outward motion, and the bending of the waves around the spherical surface of the earth. Although the mathematical relations between signal intensity and distance are very involved, the maximum distance obtainable is generally greater for greater wavelengths, other factors being equal. At the medium wave-

absent or the path followed by the sky wave in its excursion through the ionosphere is long enough to permit its separation from the ground wave on the indicator. There are a number of reflecting ionized layers whose ability to return a wave to the earth depends on their state of ionization, which in turn varies with sun position, sun spots, and other corpuscular and radiation phenomena. The intensity of the sky wave generally varies with time, or fades, because the net wave received may be the sum of several parts each travelling different lengths and having different reductions in intensity, both of which are continually changing. Reflection also varies significantly with wavelength. For practical purposes at medium wavelengths, waves are reflected only at night, so that sky wave operation must be restricted approximately to the hours between sunset and sunrise over the transmission path. During the night period ground wave transmission at medium wavelengths suffers a reduction in distance because of increased atmospheric noise. Since the reduction in intensity of the sky wave with distance is not very rapid, this mode of operation provides the greater distance of the two and is thoroughly practical for navigational use. Instead of 500 to 700 miles cited in the preceding example, the reliable night time wave transmission distance is quoted as about 1400 miles. The arrival of one or more sky waves at the receiver has proven to be a fortunate thing in pulse navigation systems. Since the energy is transmitted in short discreet bursts and the indicator spreads out the successive pulses that arrive over paths of different time delay, the navigator can make an observation on one of the several pulses, visually disregarding the others. Of course, a steady well-shaped pulse must be employed, and general experience has shown that only the first sky wave to arrive, from the so-called E_1 layer, is satisfactory. Corrections must be made for the delay in transmission caused by the increased path length and the ionized region through which the wave travels, but these corrections have been computed once for all and appear intrinsically in the Loran charts. The situation is not quite so simple at the very long wavelengths, such as those used in Low Frequency Loran, where for technical reasons the pulse length cannot be made short enough to insure separation. Also, sky waves are present even in daytime, resulting in less variation in operation between daytime and nighttime. At these wavelengths ground wave operation should be adhered to for most consistent results; it is not believed that the question as to whether consistent results may be obtained when the sky wave is very large compared to the ground wave has yet been resolved.

ACCURACY

17. As with distance considerations, the accuracy obtainable under practical working conditions can finally only be obtained from statistical results of experience. Much experience has been had with some systems, less with others, hence it is worthwhile to represent the trends and general factors based on principles and experience.

18. The most fundamental aspect of the accuracy of pulse navigation systems goes back to the accuracy with which the velocity of propagation is known. In hypothetical vacuum, the velocity of radio waves is constant and equal to that of light. For a direct wave in the atmosphere, it may vary, depending upon the dielectric constant of the region, which in turn depends on temperature, pressure, and humidity, and on any ionized condition of clouds, droplets or other particles. The ground wave velocity depends also on the characteristics of the water over which it propagates. Fortunately, the variations in velocity experienced in these cases are of negligible magnitude for all ordinary marine navigation and may be left out of consideration.* The sky wave travels partly through normal atmosphere and partly through a more or less intensely ionized region. Its velocity is quite different and variable while in the ionized region. Furthermore, the waves of the several frequencies represented by the spectrum of the train of pulses may have different velocities and different paths, with the result that some portions of a pulse may arrive at different times from others. These peculiar phenomena distort and delay the shape of the pulse received by the navigator and causes an inaccuracy in his reading. Although they do cause errors, careful operational techniques can hold them within tolerable values.

19. Another important aspect of accuracy is that of producing trains of pulses of satisfactory shape and of measuring the associated time intervals or differences. The length of the individual pulses in the train should preferably be quite short and with sharp frontal shape in order that the measurements made by the navigator of time intervals or of time differences can be accurate. There is a practical minimum to the number of individual oscillations of carrier frequency that may be worked with however, which is usually put at about 50 oscillations per pulse and as the carrier frequency is decreased the pulse duration must be made longer and longer. Lengthening the pulse duration eventually leads to degredation of accuracy. Of more concern is the problem of radiating at the longer waves pulses with very sharp fronts. The Fourier analysis of this problem, in which the pulse train is resolved into its many component frequencies or spectrum, indicates that the antenna and associated circuits must be capable of faithfully transmitting a relatively broad band of frequencies. With carrier frequencies above about 1 megacycle no unreasonable difficulty is encountered, but for frequencies of lower value, or at longer wavelengths, the design of satisfactory antennas with low Q is very difficult and their size and cost are large.

20. A third factor of prime effect on accuracy is that of the geometrical relations involved in the system. With straight radar and other radial systems, where a position is determined from a dis-

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*However, in applications requiring extreme accuracy, such as surveying, chart control, geological exploration, etc., corrections must be made.

tance and a bearing taken from the ship, or from a shore point if land-based radar were employed, the accuracy of fix generally decreases with increasing distance and with increasing wavelength. The accuracy experienced with present marine radars is quite good over the distances for which it is intended, viz. of the order of 100 yards at the close-up distances and increasing to 2% of distance at the greater values, and about 2° in bearing. Both circular and hyperbolic navigation systems depend first of all on the length of the base line between the transmitting stations, which if adequate individual station coverage is present should be as great as feasible. Circular systems which measure two distances from which the fix is obtained can be designed to give high accuracies, perhaps higher than those of any other system. As an example, the Shoran system has given probable errors of distance measurement of the order of magnitude of 50 feet in airplanes out to the limit of its range. It should be pointed out, however, that the high accuracy is in part the result of the very short pulse lengths that can be used at very short wavelengths. The reason the circular system is not well adapted to ordinary marine navigation is mainly that an adequate antenna and transmitter aboard ship is not too practical; also, a saturation of service limits its usefulness.

21. In addition to base line magnitude, the accuracy of a fix in both circular and hyperbolic systems varies with the angle made by the base line and a radial line drawn between base line center and ship and with the length of the radial line. Accuracy is greatest when the two lines are at right angles, practically zero when they coincide. Hyperbolic systems employ three or four shore transmitters and the same considerations apply although with different details. Since one pair of stations provides only a line of position, the accuracy of a fix depends on the certainty with which two lines can be determined and the geometrical relation of the shore transmitters and the ship. Proper location of shore stations is thus important. In experience thus far it has frequently been possible for the navigator to select any of several lines of position from different shore stations in order to use pairs of lines that intersect with an angle not too far from a right angle, or to select three or more lines simultaneously, which procedure may be compared to the proper choice of celestial bodies in taking star sights. The accuracy of both circular and hyperbolic systems becomes less with increasing distance but usually the practical situation does not require as high accuracies at the extreme distances as at the shorter ones. Generally, a circular system possesses a greater geometrical accuracy than that of the equivalent hyperbolic one, which may be as much as roughly 4 times as great. Experience with present marine Loran has indicated that errors of not more than about 2 miles at 500 miles can be reliably provided.

22. Accuracy of a system also depends on the manner in which

the received pulse trains are measured in order to obtain distance or difference in distances. The receivers used in pulse navigation systems customarily employ a cathode-ray oscilloscope. The trace on the fluorescent screen is controlled by the received train of pulses and by an accurately timed sweep circuit synchronized with the pulse train, providing a detailed picture of the received pulse train. The several systems differ in the manner in which the pulse interval is measured. In radar, although a plan-position indicator with an adjustable distance marker is usually employed, in principle the measurement is made by placing a distance indicating pulse in coincidence with the reflected pulse and reading the distance from the adjusting circuit calibrations. Errors occur because of finite and somewhat distorted shape of the reflected pulse and because of circuit inaccuracies. In another system, exemplified by Gee, the two pulses that are to be compared are placed opposite each other after one has been inverted. There is an inherent error in making this placement because of the apparent shape of the leading edge of the unequalized pulses. A more accurate system is employed in Loran in which the two received pulses are equalized in amplitude and then bodily superimposed on the screen, care being made to fit the leading edges. The theoretical improvement in this respect of Loran over Gee has been estimated at about 10.

23. The time required to take readings with pul[illegible]g the [illegible]avigation aids should not be greater than about 2 to 5 minutes [illegible] is only in the case of the fastest ships that any corrections for the change in ship's position between observations need be considered.

COMPARISON OF PULSE AND CONTINUOUS WAVE NAVIGATION SYSTEMS

24. Any comparison between pulse and continuous wave systems must either be extremely detailed and lengthy, or else brief and superficial. The latter course will be followed here. Fundamentally, it is possible to duplicate the pulse navigation systems with an equivalent continuous wave system, if in effect "Wave" is substituted for "Pulse" and "Phase" for "Time Difference", with corresponding associations in the transmitting and measuring systems. The measurement of phase is, however, periodic, giving rise to ambiguities of a high order in all high accuracy navigation systems which utilize phase measurements of continuous waves. Various schemes have been proposed for the resolution of these ambiguities, usually requiring the addition of secondary systems of lower order of accuracy which in combination with the basic system reduce the number of ambiguous regions. Such systems usually necessitate an extremely complicated receiver or a complex operating procedure that requires considerable time to carry out. Phase measurement systems may also eliminate or reduce the ambiguous regions, with a corresponding reduction in accuracy, by using short base line lengths of only one-half to several wavelengths between the two shore-based stations of a pair. However, the order of magnitude of error of fix

to be expected is about 25 miles or more at a distance of 500 miles for a half wavelength base line and no ambiguous region. The greater this baseline is made the higher becomes the accuracy and the larger is the number of ambiguous regions. When compared with the pulse navigation systems, these expedients appear as very elaborate equivalents of the elegantly simple pulse method which directly and with finesse solves the problem of short and long distance navigation.

25. In a continuous wave system, there is no means for separating the ground and sky waves. At very high and microwave frequencies this lack presents no difficulty, since neither of these rays reach the receivers in any case, but at medium and low frequencies used for medium and long range navigation systems, the addition of the sky wave energy to that of the ground wave with more or less random phase has a disastrous effect upon the accuracy of measurement. At distances where the sky wave is about equal in intensity to the ground wave, the variations caused by the sky waves are such as to slide the indications of phase from one region of ambiguity to another, thereby completely destroying the indication. Thus the maximum distance of the continuous wave systems is about the same as the minimum distance at which sky wave operation of pulse systems becomes useful.

26. A continuous wave system, in general, requires one channel for each transmission. A long base line hyperbolic continuous wave system would require at least three clear channels to provide a fix, while one with a short base line will require at least two channels. By contrast, many pulse systems, with their visual resolution of pulse trains, may be operated simultaneously on the same frequency by the simple expedient of assigning specific pulse repetition rates to each transmitter or transmitter pair. The navigator is easily able to select the particular transmitter he wishes to observe without interference from the others and it is estimated that between 10 and 20 such simultaneous chanel-shared transmitters are practical. This important feature of pulse systems makes them relatively economical of spectrum utilization compared to continuous wave systems.

EQUIPMENT RELIABILITY

27. There is no doubt but that the electronic gear required for pulse navigation contains many intricate and complex parts, nor that its introduction into the conservative maritime world will be met by opposition from some on this score. As an aid carried aboard ship it will require a certain reorientation of the officer personnel and the institution of a small amount of additional maintenance and operational effort. To those familiar with the successful employment of this and even more complicated equipment under the most adverse conditions of the war, there can also be no doubt about the success

with which marine radar, Loran and other similar equipment can be assimilated by those who operate ships in peace. For those who are inclined to think the difficulties are great, it may be recalled for their encouragement that some persons experienced in airplane operation were afraid that the new radar gear introduced in a steady stream during the war might not be serviceable and were later surprised, and pleased, that it could generally be kept in operation just as easily as could the plane itself.

28. It appears certain that there are a number of commercial organizations convinced and ready to back up their conviction that peacetime radar marine navigational aids will be far more rugged and reliable than any equipment of wartime vintage and quite up to the standards expected in maritime service. No doubt the magnetic compass seemed very delicate and technical to those brave men who prior to its use sailed vast water areas in cockle shells; and many of us can recall the introduction of those far more complicated devices the gyrocompass and the radio communication equipment, which are now accepted aboard as firmly as is the anchor.

29. No present or past navigational means has ever been able to provide position at every hour and with full accuracy. Celestial, lunar, and solar observations are notoriously most difficult to obtain in foul weather when needed most. The vicisitudes of dead reckoning and even radio direction finding are found in every log and in the records of marine insurance companies. Let us hope and trust that no bogey of alleged complexity will retard the availability of substantially continuous and complete navigational data from pulse systems in marine service.

PRESENTLY AVAILABLE PULSE NAVIGATION SYSTEMS

A. Short Distance Systems

1. Radar

A recent development of extreme importance to marine navigation and pilotage, has been the RADAR. As presently developed, the Radar sets available for marine use are so-called "Surface Search Radar Sets". They present, upon a cathode ray indicator, a radar picture of the region about the vessel, including indications of other vessels, buoys, and some topographic features.

31. Usually an adjustable distance indicating system is provided in the indicator, which produces a circular trace on the screen. This trace may be made to coincide with the spot caused by the object whose distance is desired, and the distance may then be read from a calibrated scale. Such a distance measuring system converts the PPI radar into a circular navigation system if two known points are identified on the screen. Accuracy of position, determined in this manner is correct to within 2% of the range; a precision somewhat better than can be obtained from range and azimuth indications. The radars for

marine use operate on wavelengths between 1 and 10 cm. The normal range from antenna heights usually available aboard ship is from 20 to 25 miles. In certain locations so-called anomalous propagation occurs with surprising frequency and then the distance may be 40 or 50 miles and even more. Unfortunately, this atmospheric condition seldom occurs during fog and bad weather and may not occur at all in most localities.

32. The radar is a versatile short distance device. It provides the most satisfactory means of warning against collision and because of the completeness of information makes ship movement in the presence of other ships not only possible but safe as well. It provides bad weather pilotage, and harbor and coastal navigation. It is self-contained in the sense that no cooperating shore stations are required. It provides the captain directly with the information from which he alone makes piloting or navigational decisions, and therefore leaves completely within his authority the movement of his ship. Its usefulness is greatly extended by the installation of suitable reflectors and radar beacons in congested waters where such aids are economically feasible.

2. Radar Beacons

33. A radar beacon is a radar receiver-transmitter combination that may be installed at some fixed location and arranged to reply to a radar interrogation with a coded response. This coding positively identifies the transmitter, and extends the maximum distance and accuracy of measurements upon the beacons. Distances in excess of 50 miles are readily achieved. Satisfactory beacon designs have been made, but there has been no extensive installation as yet. This is largely due to lack of standardization both of marine radar equipment and of beacons. The employment of beacons at a selected number of sites, including those now occupied by lights and light ships, would greatly enhance the value of shipborne radar.

B. MEDIUM DISTANCE SYSTEMS

1. Shoran

34. The Shoran system is a circular navigation system, operating in the frequency band from 220 megacycles to 260 megacycles. It consists of two beacon type ground stations and a transmitter-receiver installation. The Shoran system is essentially an aircraft positioning system of extreme accuracy over distances of perhaps 250 miles to an aircraft flying at 40,000 feet. At this distance it will give positional information accurate to within 50 feet. If adapted to marine use the distance would be reduced to perhaps fifty miles with the same accuracy. For general marine use, Shoran could be valuable as an inshore piloting aid, where its extreme accuracy would be

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valuable, although saturation of service might be a problem. It can be used as a control for hydrographic, geodetic and geologic surveying, and could be employed for precisely holding the position of a lightship or floating beacon. Shoran equipment is completely developed and complete equipments are available. No permanent installations are believed to have been made and general service is nowhere available at present, nor is it proposed.

2. GEE

35. The GEE navigating system is a hyperbolic system operating on direct waves in the frequency bands between 25 to 85 megacycles per second. It was developed as an aircraft navigation system and is said to provide coverage for any number of craft with an accuracy of from 1/4 to 1/3 mile up to distances of 250 to 300 miles, depending upon the altitude of the craft. Again, for marine use the range would be restricted to line of sight from masthead, i.e. to 40 to 50 miles. For general marine use, GEE might be useful as an inshore and coastwise piloting aid. The fact that GEE, as a hyperbolic system, cannot be saturated is an advantage in a congested region. GEE is a British development, and at present quite complete coverage of the British Isles is in existence. The equipment has proven to be reliable, simple to operate and to maintain.

C. LONG DISTANCE SYSTEMS

1. Loran

36. Loran is a hyperbolic system operating in the frequency band of from 1.7 mc. to 2.0 mc. The transmission is either by ground wave, and/or by single reflected sky wave. The primary service distance is about 700 miles from the most distant station by ground waves, with a maximum positional error of 5 miles at that distance. This distance and accuracy is available day and night, over water. At night, the first reflection from the ionosphere has proved strong and stable enough for navigation, giving a fix with an error between 5 and 10 miles at ranges out to 1400 miles from the most distant transmitter. The Loran system has been subject to an intensive development program during the last five years. The night service area of Loran presently covers one quarter of the surface of the earth.

2. LF Loran

37. The LF Loran system is a hyperbolic system operating with a carrier frequency of 180 kilocycles. It is derived from the standard Loran system and uses the same repetition rates and pulse patterns. The same receivers and indicators may be used by a small radio-frequency converter. An experimental chain was operated for about six months along the east coast of the United States. This chain has been taken

out of service and at the present writing another chain is operating in northern Canada. The low carrier frequency makes it inconvenient to make the pulses short enough to separate the ground and sky waves. However, it is usually feasible to recognize that portion of the pulse due to the start of the ground wave, so that consistent operation may be obtained, by careful operation. There is no commercial service available at the present time. It is confidently expected that the continued experiments on this system will demonstrate favorable characteristics.

THE PRESENT SITUATION

38. The present situation is full with the opportunity for progress. We have available now adequately proven electronic systems of sufficient technical capacity to solve the navigational problems of ship movement under substantially any condition of weather on oceans, along coasts, in harbors, on lakes, and on rivers. The value of such improvements in ship movement lies in the added safety and in the reduced costs of water transportation obtained when freedom from being slowed up or hove to from weather, darkness, and traffic density is secured.

39. The tremendous effort represented in this technological advance made during war should be taken advantage of now because no similar effort will be possible in a forseeable time and nothing short of it is likely to result in anything but relatively minor improvements. It will be far more profitable to establish a satisfactory system now and get the use and experience of it for years than to await the achievement of an ideal system that may elusively escape capture for many long years to come. Aviation has suffered this sad plight and is today but little further toward the operational use of all-weather aids than it was ten years ago. It is sincerely hoped that decisions will be made at this time to adopt, install and use in every-day operations a satisfactory and complete set of electronic navigation aids. If this be not done, the blame cannot be laid on the door-step of technology but must be placed elsewhere.

40. To provide a complete set of electronic navigational aids, two separate types of equipment appear necessary, one for ocean navigation possessing moderate accuracy, and a second for close-in navigation or piloting in inland waters and for warning of impending collision. No single equipment can do both jobs now or later. Different combinations of available and future equipment have been proposed, but for the various reasons advanced in this paper and elsewhere, it seems clear to this author that the combination of standard Loran for ocean navigation and shipboard radar for close-in navigation and warning is the best choice.

41. Standard Loran can now provide coverage over a very signifi-

cant portion of the ocean areas and by the addition of more shore stations can be extended and improved to give still greater service. The equipment has been thoroughly tested and is immediately available. The shipboard equipment is relatively simple and economical. Engineering-wise, there is every reason to believe that the major system design parameters were originally well chosen by its developers and can be but little if any improved. However, if later developments actually do offer improvements, it is most likely that they can be incorporated into the system without causing obsolescence of the vast quantity of navigational equipments that would presumably be in service. For example, should a very high frequency version of Loran prove of value for more accurate inshore navigation, it would be rather easy to convert the receivers to operate on this system too. Similarly, should further development of Low Frequency Loran bring about its adoption, it is believed that the same receivers could be simply converted.

42. Ship based radar is perhaps not quite so well explored as is Loran, but it is nevertheless in a high state of development. The main questions remaining involve the precise wave band in which it should operate and the degree of elaborateness with regard to piloting ease. Neither question, it is submitted, is of grave enough import to justify a protracted delay in adoption. Until a standardization of some sort is effected, the establishment of beacon stations cannot be got underway, and beacons should be installed and maintained as rapidly as possible to enhance the usefulness of marine radar.

43. With regard to future possibilities, it will be sufficient here to say that of course scientists and engineers can and undoubtedly will bring about some worthwhile new developments or improvements of present equipment. New indicators, new systems, automatic reading navigation systems, automatic controlled steering, full automatic and accurate continuous position recording, automatic collision warning, and other easily conjured up ideas may tickle the technical palate now and may, some day, but not soon, be offered for commercial use. Let's push the worthwhile new developments, but in the meanwhile, let's go ahead with what we've got!

ACKNOWLEDGMENTS

44. The author wishes gratefully to acknowledge the valuable assistance of Messrs. Winslow Palmer and R. L. Frank, Project Engineers of the Sperry Gyroscope Company in gathering material and aiding in the preparation of this paper, and for the generous loan of slides or other material by Dr. J. A. Pierce of Cruft Laboratory, Harvard University, Mr. D. G. Fink of "Electronics", McGraw-Hill Publications, Mr. Earl Anderson of R. C. A. Industry Service, Mr. M. Pomerantz of the Watson Laboratories, A.A.F., and Lieutenant Commander L. E. Brunner of the U. S. Coast Guard. Further in the background are the published papers and work of some of these, of

many others in the N.D.R.C., Radiation Laboratory, U.S. Navy and Coast Guard, Army Air Forces, and commercial laboratories in this country and of similar individuals and groups in England who have contributed to the splendid development of pulse systems so effective in the war and now to be of equal value in the commerce of the seas, lakes, and rivers of the world.

W. L. BARROW
SPERRY GYROSCOPE COMPANY, INC.
GREAT NECK, NEW YORK

Attachment to
IMMRAN Doc. 21

PULSE NAVIGATION SYSTEMS

by

W. L. Barrow

List of Illustrations

A-3456 0 +

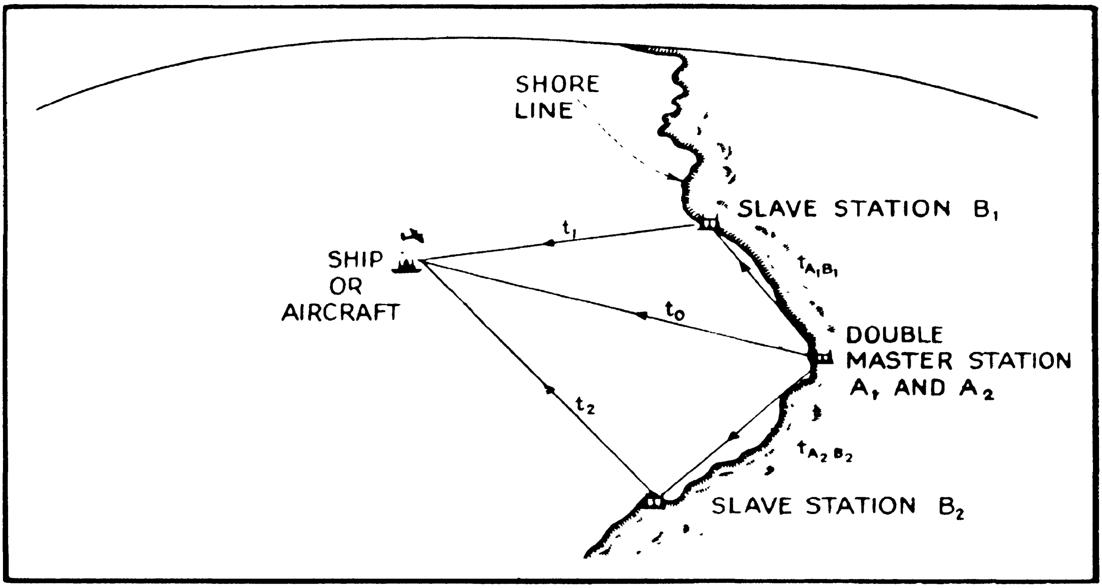
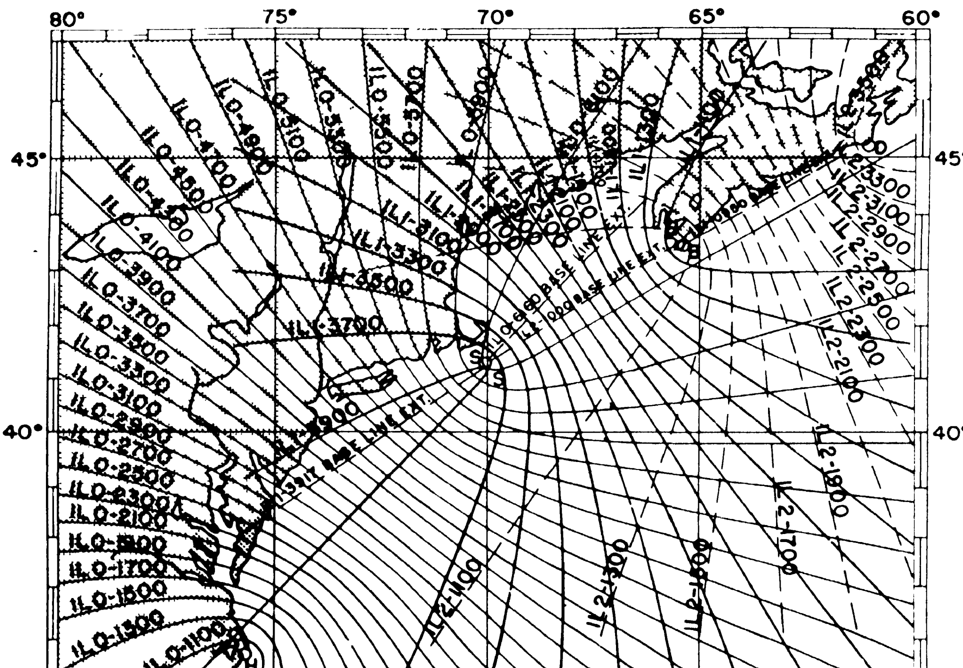


Figure 1 - Geometry of Hyperbolic System.



REPRESENTATIVE LORAN NAVAGATIONAL CHART

Figure 2 - Representative Loran Navigational Chart.

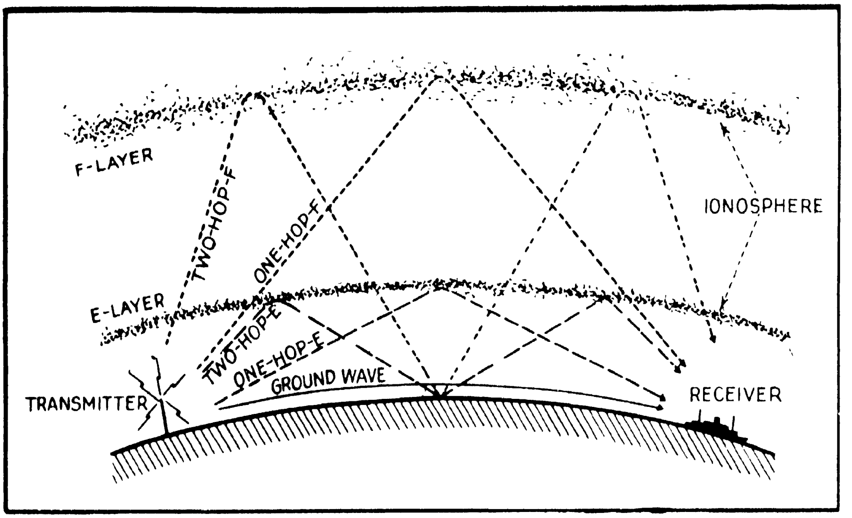


Figure 3 - Paths Followed by Radar Transmissions.

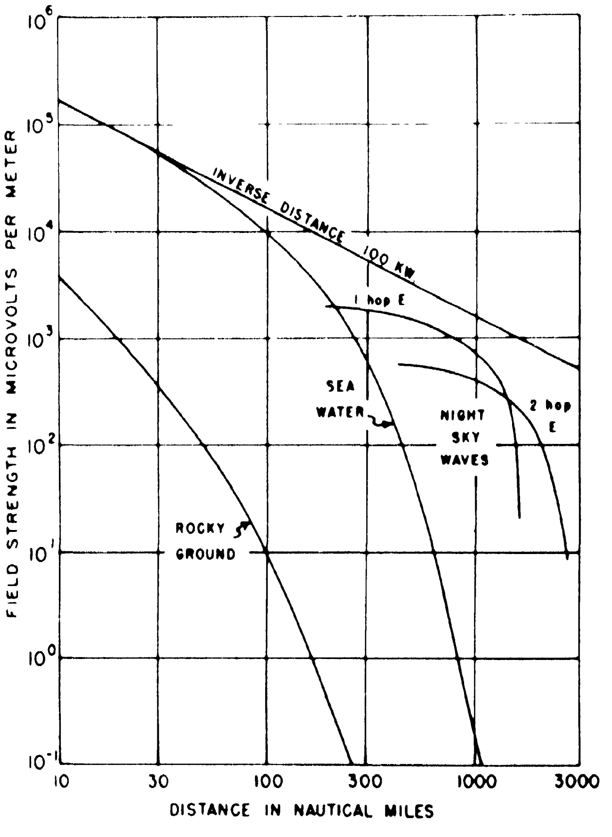


Figure 4 - Field Strength of Medium Frequency Waves.

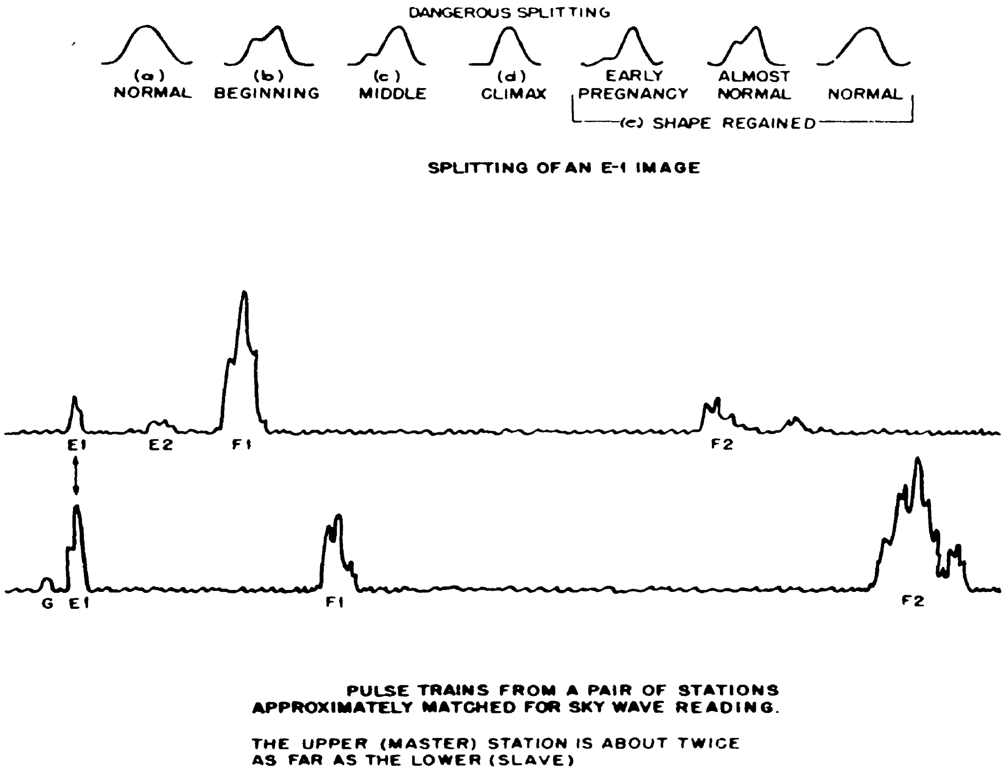


Figure 5 - Pulse Trains at the Receiver Due to a Single Transmitted Pulse.

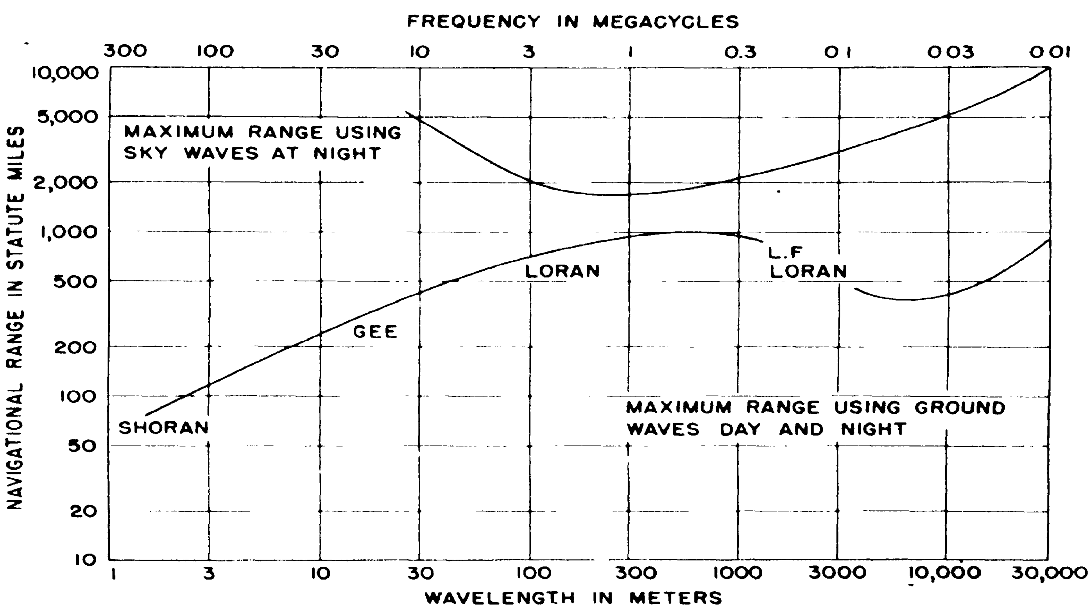


Figure 6 - Representative System Ranges.

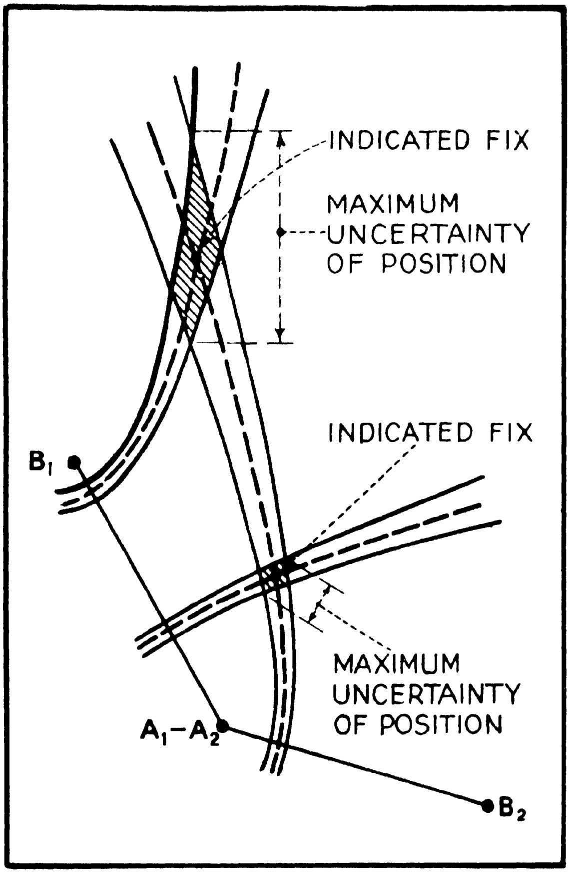


Figure 7 - Relation of Accuracy Affixed to System Geometry.

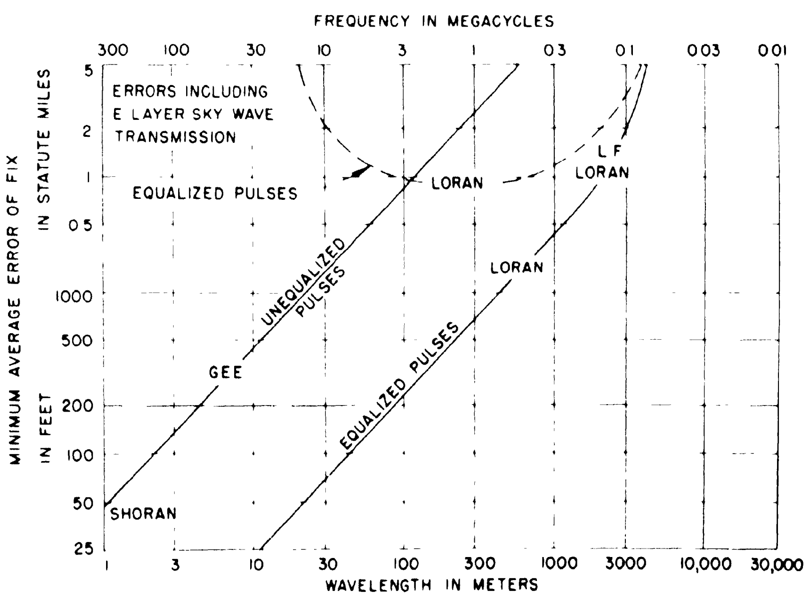


Figure 8 - Representative System Accuracy.

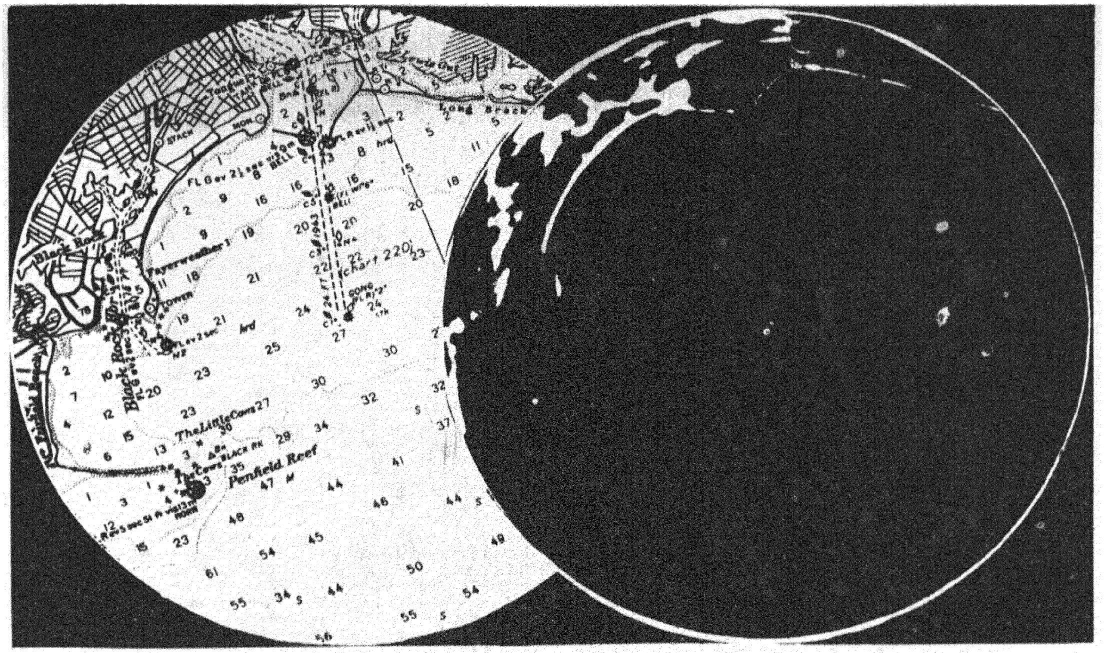


Figure 9 - A Typical Radar PPI Presentation and Corresponding Chart.

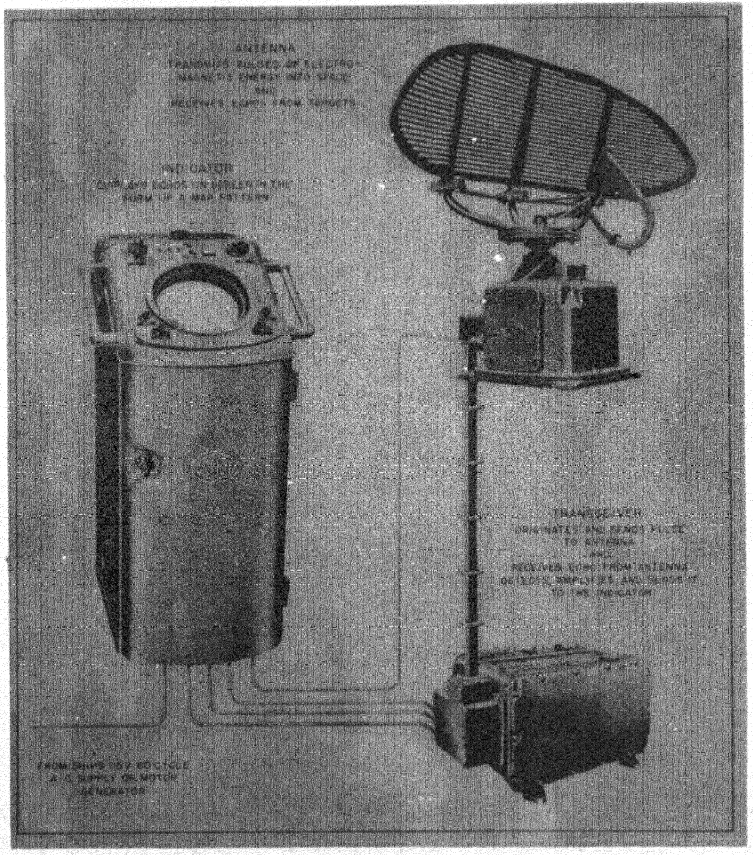


Figure 10- Typical Radar Equipment.

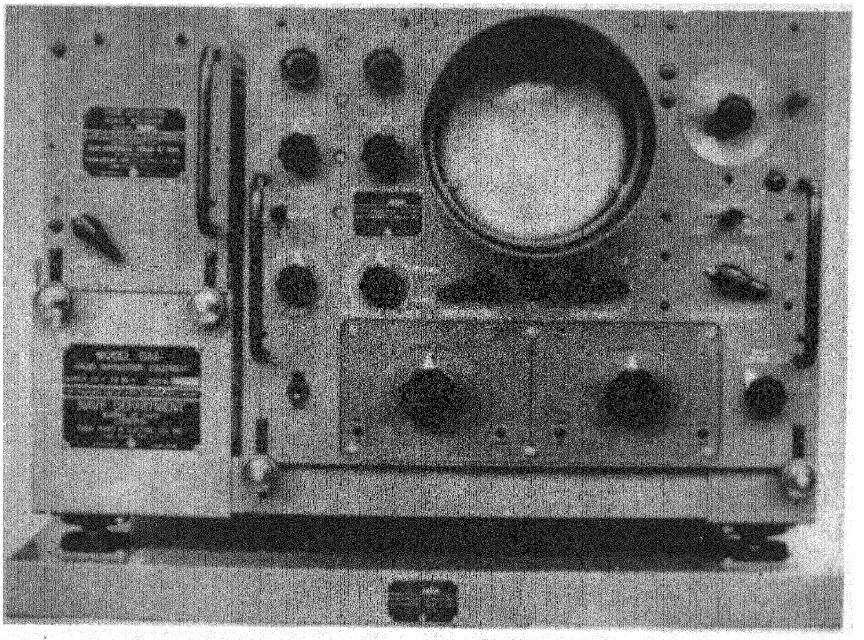


Figure 11- Early Type of Loran Receiver.

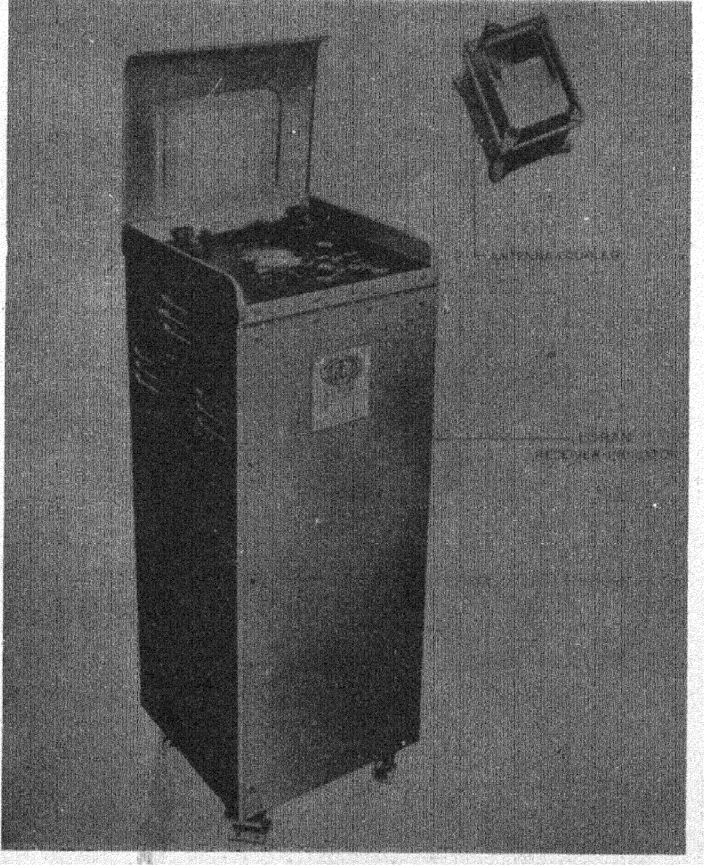


Figure 12 -Marine Loran Receiver.

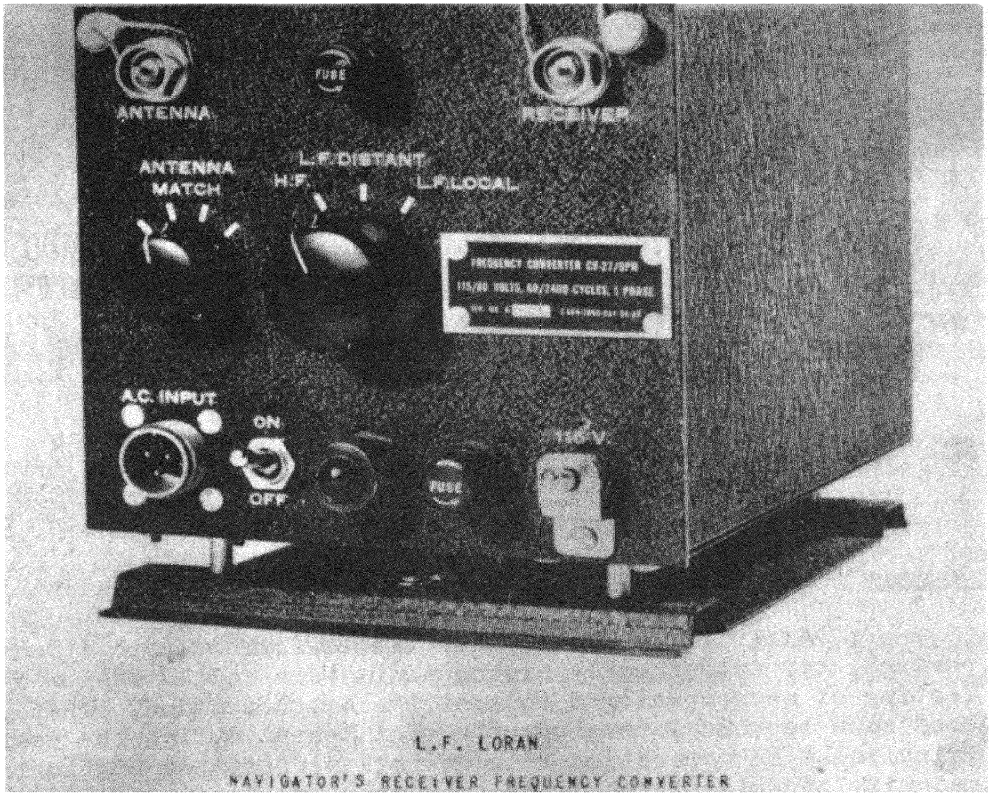


Figure 13- Conversion Unit for LF Loran.

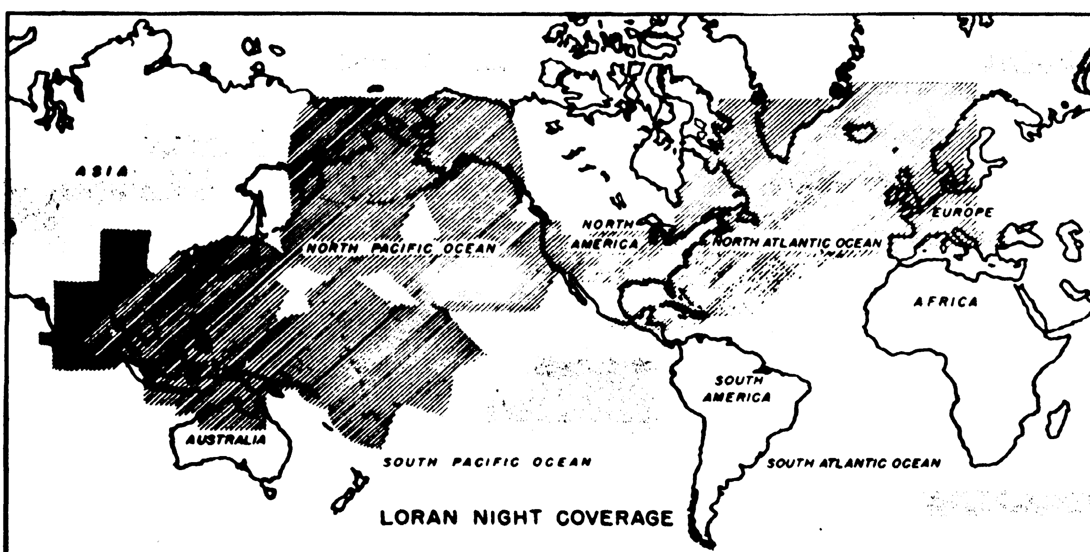


Figure 14- Extent of Loran Coverage at the End of the War.

IMMRAN DOC. 22

U.K. PAPER NO.6

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION

NEW YORK CITY AND NEW LONDON, CONN · · · APRIL 28-MAY 9, 1947

3-CM SHIPBORNE RADAR
PROGRESS IN THE U.K. SINCE FIRST IMRAMN

Summary

After first IMRAMN the U.K. Performance Specification was revised, and subsequently arrangements were completed for Type Testing of sets developed to meet the specification. There have been some technical developments of interest during the year, principally in connection with overall performance monotoring. The majority of sets fitted during the year are Type 268 and much operational experience has been gained with this equipment. The number of commercial sets fitted is increasing; two firms are now in production with equipment which has already demonstrated its value. Substantial progress has been made in radar training for Merchant Navy Officers and facilities for maintenance at ports both in the U.K. and overseas are being considerably extended.

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1. Introduction

The establishment of centimetric PPI Radar in widespread use as a Navigational aid to Merchant ships involves activities of many different kinds, and this review of progress in the U.K. since the first IMRAMN meeting does not attempt more than a brief description of some of these activities, in connection with specification and type Testing, Technical Developments, Operational Trials and Experience, and Training and Maintenance.

2. The U.K. Specification

Immediately after the first IMRAMN Meeting the specification for a ship-borne radar set which that meeting had considered (Volume II of I.M.R.A.M.N. Report p.98), was reviewed by representatives of Government Departments and the Radio Industry, and a revised specification was issued, which was printed in Volume II of the I.M.R.A.M.N. Report, p. 104 (U.K. Paper No. 2)

The revised specification is divided into two sets of clauses, called "Mandatory Features" and "Code of Practice". The mandatory clauses refer to the characteristics of an equipment and its performance which are essential for safety and for navigation in pilotage waters. It should be noted that the performance requirements of the original specification have been maintained; that clauses have been added specifying minimum standards of quality of components, mechanical construction, and finish; and that the standards of climatic and durability testing have been defined by reference to a specification applicable to all Marine Radio Equipment.

The Code of Practice clauses are recommendations on design practice, maintenance, ancillary devices, and accessories, based on those clauses of the original specification and its appendix which refer to desirable but not essential requirements.

3. Type-Testing

The agreed procedure for type-testing of commercial navigational radar sets will include climatic and durability tests and observations of operational performance.

To facilitate the performance tests, and to avoid the necessity for trials with a variety of targets, the "U.K. Radar Set" demonstrated in "H.M.S. FLEETWOOD" during the first I.M.R.A.M.N. Meeting, has been set up at a shore station by the sea near Portsmouth. The range performance of this set against various targets has been determined, and the amount by which it exceeds the requirements of the Performance Specification is known. The range performance of any other set will be determined by installing it at the same site and comparing the performance of the two sets against a single target ship. The "U.K. Radar Set" has been calibrated with various ships of the type which will be used so that allowance can be made for variations due to meteorological conditions or to variations in performance of the "U.K. Radar Set". This procedure will enable the range performance of any commercial set to be reliably estimated with the minimum of expenditure on range trials with ships.

In order to enable the range and bearing discrimination to be determined without using ship targets, a pattern of buoys carrying corner reflectors is laid in a convenient position offshore. The relative positions of the buoys have been selected so that it is possible to determine very quickly whether the set under test complies with the requirements of the specification in these respects.

The exact procedure for determining the minimum range is being worked out.

Supplementary tests of the electrical properties of units of the set will be made.

A life test of a typical equipment from a manufacturer will be carried out for 250 hours, made up of at least one period of 50 hours and shorter periods of not less than 8 hours.

After some date in the future, when a reasonable number of commercial radar sets are available, only sets which conform to the U.K. performance specification and have a certificate of type-approval will be allowed to be installed in U.K. ships.

4. Technical Developments

The main characteristics of navigational radar are unlikely to change for many years, but improvements in detail are possible, particularly in reducing the effects of sea-clutter, in overall monitoring equipment, and in chart comparison units. There is no progress to report in the development of the larger and brighter display which would be so valuable in marine radar.

4.1. Reduction of Sea Clutter

During the trials with the U.K. Radar set in "H.M.S. FLEETWOOD" in Norwegian waters in June 1946, it was noted that an improvement in the circuits for reducing the effects of sea-clutter was desirable, and that in order to effect such improvement more knowledge was required of

a. the effect of the TR switch in reducing receiver sensitivity at short ranges (50-1000 yards), and

b. the law of variation of sea-clutter power with range, at short ranges.

An investigation has been carried out on a. and arrangements are in hand to carry out trials on b. in the near future. When these are completed improved circuit arrangements can be developed to simplify further the operation of marine radar in narrow waters.

An interesting development which may ultimately lead to a major simplification in operation procedure is that of the "logarithmic receiver" (in which the output is proportional to the logarithm of the input). By the use of a receiver of this type the effects of sea-clutter, and also of clutter due to rainstorms, can be minimised, and ships and other targets displayed without use of the gain control, whereas, with a conventional receiver, skilful use of this control

would be necessary. The application of this technique to receivers of wide band-width, such as are used in navigational radar sets, depends on the development of special components, and some years may elapse before this is complete.

4.2 Overall Monitoring

The problem of developing satisfactory and reliable overall monitoring equipment is one of particular importance, where there is wide scope of ingenuity. The apparatus developed for use with the U.K. Radar Set is more complex than is desirable, and an alternative system has been developed. This comprises a simple echo-box of low ring-time; a portion of the signal returned by this is strobed and integrated for meter indiction and relay operation if desired. A difficulty is to ensure a standard reference level of noise at the selected range where the strobe operates, since this is at a point where wide variations due to sea-clutter normally occur. Simple methods of ensuring this standard level are being investigated. The system has the advantage over the previous system, not only of simplicity, but also of giving a true overall check of the set including the TR switch which is not checked by the present system.

The most notable commercial development in this field is an improved "delayed-pulse oscillator" system. In this system the transmitted pulse is received by a simple superheterodyne receiver, and the Intermediate Frequency signal is converted to a supersonic pulse and applied to a supersonic delay line, where it undergoes multiple reflections. The reflected signals are re-converted in the frequency changer to the radar frequency, and received by the radar receiver, which displays a train of pulses capable of being used to measure the efficiency of the radar set. A difficulty when using a standard crystal mixer is that the attenuation required between radar transmitter and monitor (to prevent crystal burn-out by the transmitter pulses and to reduce the imput to a value which gives linear frequency changing) is so great that the power of the reflected signals (after passing through the attenuator on the return path) is too low. The improvement in technique consists in using the local oscillator as an "autodyne" mixer for the transmitter pulses, and using a crystal mixer with the same local oscillator to re-convert the delayed pulses of IF back to the radar frequency. This enables a much larger input from the transmitter to be used, with consequent improvement in the power of the reflected pulses received by the radar set. When this development is satisfactorily completed, it will form an elegant solution to the overall monitoring problem. It is, of course, open to the objection that the monitoring equipment includes a 3 cm. local oscillator valve which is one of the components of the radar set of comparatively short life, for which an improved design is very desirable.

4.3 Chart Comparison Units

Interesting work is proceeding on two optical systems for chart comparison. In one system, the radar display screen is viewed directly through a large lens which gives a slight magnification (1.5: 1). An image of the chart is superimposed by means of a lens and mirror system. The observer views the picture with his head in the normal erect position, and there is no restriction on head movement within moderate limits; another advantage is that the chart can be illuminated normally and used directly, and the brightness of the image which is compared with the radar screen can be adjusted by means of a filter in the optical system. In this system the magnification of the radar picture is limited to about 1.5: 1 because of the accommodation properties of the human eye.

The specified resolution of the radar display is such that an optical magnification of 2.5: 1 could be profitably used, to allow direct comparison with large scale charts without undue restriction of the radar field of view. An optical system is being developed, which will give any desired magnification of the radar picture for direct chart comparison. The chief disadvantage of this system from the operator's point of view is that it involves monocular viewing with a fixed head position, and it remains to be seen whether the advantage of a substantial magnification of the display outweighs this disadvantage.

5. Production and Operational Experience

A number of manufacturers have designed marine radar sets to meet the U.K. specification. As this specification prescribes only the performance of the set there is considerable scope for individualism in layout, mechanical design and in circuit and constructional details. The general practice has been to construct a small number of prototype sets and to fit these to ships to give operational experience prior to full-scale production. The first British commercial radar sets were installed in ships in the summer of 1946 and the number of ships equipped has steadily increased. Some manufacturers are now in full production.

As the U.K. reported at first IMRAMN naval radar sets, type 268, are being hired to merchant ships until commercial sets are generally available. These sets fall below the performance required by the U.K. specification and will later be withdrawn, but they have been of considerable service operationally to merchant ships. The type 268 and the commercial sets have made Navigating, Radio and Engineering Officers familiar with the operation and technicalities of radar, and have provided very valuable operational experience for ships' officers, shipowners, and designers.

Some details of the ships fitted and of the reports received from them of experience in all parts of the world are given separately in another paper (U.K. paper No. 11) and these shew the great value of 3 cm. radar as a navigational and anti-collision instrument. Very few of the reports refer to any adverse effect of rain - clutter and none shew it to be serious; some reports refer to the ability to detect other ships and to recognise landmarks in rain clutter by use of the gain-control. No reports have been received of "black-outs" due to rain storms.

All the experience of the U.K. confirms the advantages of a wavelength of 3 cm. for marine radar. Reflections of side-lobes from large rock faces and multiple reflections between rock faces are shewn to be negligible in a report of trials in the Norwegian Fjords (U.K. paper No. 12).

6. Miscellaneous

The U.K. has given further consideration to the use of passive and active radar responders and has considered in some detail the design of charts for use with radar. The facilities for maintenance ashore of marine radar equipment have been extended, and arrangements have been made for training merchant navy officers in radar operation and maintenance. Details of these advances are given in separate papers.

i.e.	Passive responders	-	U.K. Paper No.	7
	Radar charts	-	"	8
	Radar maintenance	-	"	9
	Radar training	-	"	10

IMMRAN DOC. 23

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN. · · · APRIL 28 - MAY 9, 1947

STANDARD LORAN IN THE MERCHANT MARINE

-By-

Commodore H. Manning, USMS
Master, S. S. AMERICA

ABSTRACT

In this paper the speaker discusses some of the practical factors affecting successful use of Loran as an aid to Navigation. He particularly stresses the need for additional Loran coverage in the approaches to the British Isles and emphasizes the importance of training in the use of this as well as all other electronic aids.

STANDARD LORAN IN THE MERCHANT MARINE

When a Loran receiver was first installed aboard my vessel last September, I must confess that I viewed it with some suspicion. Now, after having used it extensively, I feel that I would not want to be without it.

As many of you know, the past winter has been particularly severe in the North Atlantic. On several occasions, celestial observations have been impossible for 3 and 4 days running, and on one voyage I was able to obtain but one celestial fix during the entire passage from New York to Cobh. During these voyages the ship had to be navigated by dead reckoning, established and aided by Loran. The system has proved its value to me as an aid to ocean navigation by helping to keep the ship on her course line, thereby saving distance and time. By this I do not mean that the Loran system is a cure-all for ocean navigation. Rather, it should be used as an aid to navigation, in conjunction with other available means at one's command.

On normal trade routes between the East Coast of the United States and the British Isles and northern France, there are some areas in which the existing Loran coverage is inadequate. I believe that, if it were possible to increase the power of the present transmitting stations and to establish an additional station at the approach to the British Isles, adequate coverage of the entire trade routes between such areas could be obtained. If another station were to be added, working in conjunction with an existing station to form a new station pair, the orientation should be of such fashion that the new center-line is parallel or nearly parallel with the circles of latitude. The new, proposed rate used in conjunction with present rate 1L5 would afford a good approach to the land until the vessel is within radio direction finder range.

The accuracy of this system depends on the relative location of the vessel with respect to the transmitting stations and on the skill of the operator. If the vessel is near a base-line extension, a large error will result in the readings. Also, the farther away the vessel is from the transmitting stations, the poorer will be the line of position due to the divergence of the lines. In the latter case, the magnitude of the error is in the order of 2 or 3 miles. The human error is probably the largest error in the system. Unless it is known that one is definitely inside or outside of the ground wave coverage area, care should be taken to identify the type of signal one is dealing with. In most cases,

if a ground wave and a sky wave are unintentionally matched and a reading is taken, the position line will be sufficiently in disagreement with the dead reckoning position that the matching error will be readily apparent. There is always a possibility in certain areas that the error in mismatching sky waves may be so small that the error will not be detected, and when used in conjunction with another line of position where the crossing angle is small, the resulting fix may be several miles in error.

On three occasions, the second-hop "E" sky wave has been used with good results when outside of the first-hop "E" sky-wave range. Naturally, these lines were used with great caution and then, only as an indication rather than as anything definite. The rate was 114 in about 51 North, 16 West. Each time, the results from these readings turned out satisfactorily when checked back.

I have found that the accuracy of the system in practice averages from 2 to 3 miles, depending upon the relative angle of the ship with respect to the Loran transmitting stations, the distance, and the electrical noise or static conditions. Heavy static is the cause of a great deal of time spent in getting a good average reading for a position when the sky waves are weak.

On my last voyage, upon approaching Nantucket Light Vessel from the east, Loran fixes were obtained, using rates 111 and 110. In this area the positions should be very accurate because the 20 microsecond divisions on the charts are very close together, the lines run at nearly right angles to each other, and the area is covered by strong ground waves. The results checked with radio direction finder and Radar when within their respective ranges and showed the Loran position to be within a mile of the actual ship's position. In the absence of good celestial observations, this is considered to be quite excellent.

A very practical precaution, which should always be observed, is to turn on the Loran receiver for about 5 minutes prior to taking a reading. This is necessary to allow the equipment to warm up sufficiently to prevent creeping.

It will be interesting to follow developments in the matter of Loran charts to see which type will eventually be adopted. When separate Loran charts are used, the position thus obtained must be transferred to the regular navigational chart. About 6 months ago, the U. S. Coast and Geodetic Survey introduced a system in which Loran lines of position were printed on the reverse side of a coastal chart. This system eliminates transferring from one chart to another by simply pricking a small hole on the Loran curves and turning the chart over for the position. However, if a ship steamed the same track over and over again, such

treatment would require the use of new charts for each voyage in order to eliminate confusion from the previous voyage in picking out the right prick point. If Loran lines were superimposed on the face of small scale coastal charts, the latter would have to suffer in navigational detail. Each one of these systems has its advantages and disadvantages, but possibly the surest system is the original two-chart system.

In conclusion, let me point out two factors that are unquestionably the important factors to safety and to success with Loran. The first is the need for proper and adequate Loran transmitting stations. I have found a need for more stations, when approaching the British and Irish coasts. It is there that the importance of a fix is emphasized and I have often lamented the weak coverage of Loran in those localities. I plead that the axe of economy may not eliminate the stations already established. Boldly I seek to economize on other matters—not on Loran or any other navigational aids. So much more is demanded of ships in the present day than heretofore that all aids should be developed, not retarded. The second factor is the personnel problem. It is absolutely essential that the operator of Loran be a trained person. Without training in the operation of this and other instruments, the operator becomes a menace, not an aid, to navigation. All deck officers should be compelled to take a course of instruction such as that offered by the U. S. Maritime Institute at New York. A few days will suffice; of course, the more thorough the instruction, the better. Personally, I would make this mandatory, with an adequate endorsement on the officer's certificate. This philosophy of trained personnel has been neglected. The complexity of new ships in construction and electronic instruments makes it imperative. Without trained personnel it is useless to develop these instruments, as in the last analysis the safety of the ship depends on the personnel.

H. MANNING
Commodore, USMS
Master, S. S. AMERICA

IMMRAN DOC. 24

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN. · · · APRIL 28-MAY 9, 1947

PRACTICAL PROGRESS IN LORAN FOR MARINE NAVIGATION

-By-

LAWRENCE M. HARDING
CAPTAIN, USCG
U. S. C. G. HQ.

ABSTRACT

This report briefly summarizes some of the practical experience had in providing Loran service and in actual operational use of Loran by merchant ships and civil aircraft in the ten or eleven months elapsed since the London May 1946 IMRAMN meeting, especially in the following particulars:

(a) Report of simple methods used to alleviate or eliminate interference to other radio services in or adjacent to Loran frequency channels and summary of technical characteristics of new and improved postwar Loran ground station equipment.

(b) Estimates of costs of operation of a new postwar Loran station in terms of men, money and frequency band.

(c) New operational experience in using Loran on small craft, experience in use of Loran for medium distance navigation and some information on use of Loran by ocean air lines.

PRACTICAL PROGRESS IN LORAN FOR MARINE NAVIGATION

Introduction

1. Last year at the London IMRAMN the U. S. delegation described the wartime experience with Loran and discussed the potential use of Loran for merchant shipping navigation. At that time the U. S. delegation suggested that whether or not the merchant mariner needs such service would be determined pretty largely by economic considerations affecting the sailing time and operating costs of the particular ship.

2. At this new meeting you are hearing some further U. S. views from (1) an experienced large-ship officer who has had use of Loran in the past year; (2) a spokesman for the small craft navigator, and (3) a spokesman for a U. S. shipowners' federation.

3. At the London IMRAMN some questions were asked by delegates about reports of interference by Loran stations to adjacent services, notably small fishing boat communications in the Eastern Atlantic. Other delegates asked some questions about the number of men required to operate a Loran station for peacetime use. Another delegate asked why merchant ship radar supplemented by a system such as Loran could not serve as a complete system of electronic navigation. As a result of these questions we have endeavored to obtain some practical operational experience in these three phases during the past year and present herewith some brief summaries of these experiences for the information and use of other delegates to this meeting.

REPORT OF SIMPLE METHODS USED TO ALLEVIATE INTERFERENCE TO OTHER RADIO SERVICES IN OR ADJACENT TO LORAN FREQUENCY CHANNELS

4. In connection with some reports received at the London IMRAMN meeting concerning interference caused by Loran signals to other radio services operating on adjacent channels, efforts were made to obtain definite data pertaining thereto such as frequencies involved, time and location of specific instances. In the year which has since elapsed, only two definite cases of such interference have been found in the Western Hemisphere. One concerned interference on frequencies between 1560 and 2350 KC which are used by the Icelandic fishing fleet in the waters adjacent to the Loran transmitting station at Vik. The other report came from a commercial marine radiotelephone station at Charleston, S. C., U. S. A., which uses a working frequency of 2174 KC. The following descriptions of the methods used in eliminating the interfering signals demonstrate the relative ease with which suppression of any interfering pulsed navigational signals can be effected by the use of simple pulse limiters or filters. This is one feature of pulsed systems which has not heretofore been fully discussed at these meetings.

5. Upon receipt of a report from Iceland which stated that interference from a Loran transmitter was being encountered in the Iceland area, PICAO assigned a radio engineer to conduct an investigation in that area. The following is a brief summary. The icelandic fishing

fleet, which at present comprises some 600 vessels, was authorized by the Cairo Convention to use the frequencies between 1560 and 2350 KC for ship-to-shore and ship-to-ship radiotelephone communications. Since the great majority of the boats are small and manned by non-technical personnel insofar as radio equipment is concerned, the radio equipment must be small and simple of operation. The transmitters are usually crystal-controlled, with provision for operation on any one of three frequencies by the operation of a single control. The calling and distress frequency, 1650 KC, is used by all vessels; the other two may be any frequencies in the authorized band. The nominal power output varies from 6 to 10 watts in the small boats to approximately 25 watts for the large, off-shore trawlers. For reception the vessels use a 6-tube superheterodyne receiver, designed and constructed by the Iceland Dept. of Posts and Telegraphs. The characteristics of this receiver were found to be very good. The sensitivity is on the order of 2 microvolts per meter for a standard output of 50 milliwatts, with a selectivity of approximately plus or minus 3 KC at 6 db down. The relatively low output of the transmitters and the difficulty of providing an efficient antenna aboard such small boats are offset by the high receiver sensitivity. This is normally a good engineering compromise. In the case at hand, however, the higher-order side bands from the Iceland Loran transmitter (operating on a frequency of 1950 KC with a peak carrier power of 100 KW) were of sufficient intensity to override the comparatively weak signals from the ship transmitters, practically precluding radiotelephone operation on frequencies within plus or minus 50 KC of the transmitter carrier frequency, at distances up to 75 miles from the transmitter.

6. Another factor discovered by the PICAO engineer was that the "Tee" type transmitting antenna of the Loran station has been shortened on several previous occasions as a result of storm damage to supporting structures, and the antenna tuning unit range was inadequate to compensate for the change in reactance. This resulted in an incorrectly terminated transmission line, which in turn resulted in a badly distorted pulse and an unsymmetrical distribution of side bands. Subsequent tests, and the use of a filter across the transmission line of the Loran station as a temporary measure disclosed that incorrect station operation was responsible for a large part of the interference reported.

7. The PICAO engineer, with the full cooperation of officials and technicians of the Iceland Dept. of Posts and Telegraphs, conducted tests in the Department's laboratory and in a specially equipped ship. The results of the tests indicated that while transmitting filters were both effective and practical immediate suppression could be most easily accomplished by the use of a pulse-limiting circuit in the receivers. Laboratory experiments were then made to determine the circuit and constants best suited for Loran suppression. A limiting circuit was developed and installed in a standard Posts and Telegraph receiver for tests in the immediate vicinity of the transmitting station. A detailed presentation of the application of limiting circuits in communications receivers is beyond the scope of this discussion. It is believed sufficient to say here that all limiters are essentially

restrictive devices designed to reduce, or limit, the output of a stage to a certain predetermined level. The Loran pulse, being of very short duration must have a large amplitude to contain any appreciable power and by taking advantage of this fact (which is an exclusive feature of pulsed-type signals), the design of a suppression ciruit became a comparatively simple problem. The inclusion of a limiter circuit in the second detector of the receiver prevents the application of a strong pulse to the audio and reproducing sections of the equipment. The distortion introduced is negligible in the reproduction of speech. In later tests, it was found that a simple shunt limiter, utilizing a type 1N34 crystal diode gave very satisfactory suppression in the immediate vicinity of the Loran transmitter (better than 15 db reduction in the amplitude of the instantaneous Loran pulses). This limiter is simple to install and the cost is very small (about 2 or 3 dollars). A series type limiter built around 6H6 diode had even better characteristics giving better than 25 db reduction. However this latter type involves a more extensive and somewhat costlier modification and is considered hardly worthwhile for general use on small craft but it would be ideal for use at shore stations or any installation where extreme attenuation is necessary. It is important to note here that the use of a simple and inexpensive limiter in radio receivers has obvious advantages other than to simply remove Loran interference since it is a very effective means of reducing many forms of electrical and atmospheric interference, whether man made or natural interference.

8. One American Telephone and Telegraph Co. Coastal Harbor radiotelegraph installation at Charleston, S. C., U.S.A., reported interference from the Loran transmitting station at Folly Island, S. C., approximately 5 miles distant. Upon investigation by a U. S. Coast Guard engineer it was determined that the interference was due to minor sideband radiation on 2174 KC, 224 KC above the Loran carrier frequency. This is a rather unusual case since the receiver was operated at very high sensitivity in a standby condition and therefore was responsive to interfering signals of very small magnitude. Possible alternative means of attack in this case were electronic blanking switching at the receiver, wave traps at the receiver, directional antenna at the receiver, limiter at the receiver, and filters at the transmitter. In this particular case it was expedient to use corrective means at the transmitter since the interference involved only a single frequency. A satisfactory solution was attained in the development of a high-Q side-band filter which was installed in the transmission line of the transmitting equipment and tuned to the interfering frequency, 2174 KC. With this filter installed, measurements showed the attenuation of the interfering side bands to be on the order of 20 db, a degree of suppression sufficient to reduce the interfering side bands to the ambient noise level of the area concerned. These methods of eliminating interference, although relatively simple, are expedients necessary only on some present Loran stations. The characteristics of the new stations preclude the need for expedients at transmitting stations.

TECHNICAL CHARACTERISTICS OF THE NEW POSTWAR LORAN GROUND STATION EQUIPMENT

9. New Loran ground station transmitting equipment is now under construction for installation in the near future. It provides considerably higher power, narrower bandwidths and increased radio frequency stability. Standard Loran now occupies a nominal 0.1 megacycle bandwidth but the new equipment is expected to reduce this bandwidth by about one-third with little or no detrimental effect on system accuracy or any change in the basic system except for considerably increased Loran service radius, improved signal to noise ratio, and a reduction in interference to and from other services, all accruing from the reduced bandwidth. The reduction in interference is illustrated by the following brief table:

	Utility Spectrum		Interference Spectrum	
	3 db down	6 db down	20 db down	40 db down
Present Loran Stations	20 KC	35 KC	115 KC	275 KC
New Loran Stations	18 KC	37 KC	75 KC	110 KC

This table shows the reduction effected in the interfering outer side bands with little or no effect on that part of the bandwidth which provides the inherent accuracy of the Loran system through steep pulse fronts and clear separation of ground and sky waves. Through use of higher power the present nominal daytime average service radius of 750 nautical miles will possibly be extended to around 1000 miles but the most distant night service would probably remain at the present nominal 1400 mile radius. There are even remote possibilities, through advanced receiver-indicator design, of extending the daytime service to as much as 1200 miles. These seem to be the immediate approximate long distance limits of exploitation of the Standard Loran system without extended research.

OPERATING COST IN PERSONNEL, MONEY AND FREQUENCY

10. Loran transmitting stations in wartime were often operated with a personnel complement consisting of nine to thirteen technical people plus supporting members such as cooks, base maintenance men, etc. This comparatively large complement was typical of that required by any newly developed system operated under wartime conditions. Since the conclusion of the war the further perfection of automatic equipment accompanied by studies and tests as to how these may be safely utilized with a minimum of operating people has resulted in the plan to employ only four tech-

nicians to operate each new station or old station as it becomes completely modernized. The number of supporting people will be correspondingly reduced so that it is expected that the total staff will be similar to that used at an ordinary lighthouse, radiobeacon and fog signal station. Where a Loran station can be installed at an existing activity such as, for example, a lighthouse, the extra personnel required will be very small.

11. Similar treatment of Loran monitor stations is expected to result in the assignment of not more than one or two technicians and where the station may be combined with another activity such as a lighthouse it may be unnecessary to supply any additional personnel for Loran purposes. Monitor stations are normally located so that they may serve two or more Loran rates. The new equipment will not be constantly supervised since it is fully automatic but it is equipped with alarm devices and will be attended.

12. In comparison with older types of radio aids to navigation the cost of Loran service operation may at first appear to be high. However, when the factors of range and accuracy are considered Loran appears to be economical. For example, a comparison with radiobeacon installations follows in the table below. The number of stations of each type is that required for a navigational line of position along a coastal area.

System	Sq. Miles Day Area	Sq. Miles Night Area	Accuracy Day	Accuracy Night
Class A Radio-beacon (1 sta.)	62,500	62,500	2.0° at 200 miles	2.0° at 200 miles
Loran 100 KW (2 sta.)	644,000	2,274,000	0.2° at 800 miles	0.3° at 1500 miles

In terms of maintenance cost, one new Loran station costs roughly about the same as one Class A radiobeacon station for power supply and salaries. The cost of electronic supplies is about 10 to 15 times greater for a Loran station but this is usually a small part of the total operating cost.

13. The physical space requirements for Loran are relatively small. The entire lot of equipment requires floorage of approximately 900 to 1200 square feet. At the frequency of 2 megacycles the antenna dimensions are extremely practical. The U. S. Coast Guard standard Loran antenna consists of a 120-foot steel tower, although for a few contemplated higher

power stations a relatively inexpensive 300-foot tower will be erected. As contrasted to certain other types of navigational aids employing directional antenna arrays requiring considerable ground space, ranging up to several miles, each Loran station requires space for only one transmitting antenna plus a simple single receiving antenna.

14. The maintenance charges on Loran equipment are similar to other radio stations of comparable size and average power. There are required only the usual replacements of tubes, capacitors, resistors and transformers typical of electronic equipment. The high power and resultant long range of a Loran station is achieved by the pulse method, producing an effective radiated power one thousand times that of a communication or radiobeacon transmitter having equivalent power consumption.

15. Although the width of a single Loran channel may at first introduction appear quite large a brief investigation of the method by which the channel is used immediately discloses features of real frequency economy. The different Loran pairs of stations are identified by being made to pulse at a slightly different number of pulses per second, an operation which is entirely disassociated from the radio frequency channel upon which the stations transmit. It has been found practical to transmit as many as 16 different pulse rates superimposed in any one world area upon a single radio channel in spite of the fact that each rate occupies the entire channel. Thus, if the useful width of a Loran channel is 40 kilocycles it can be considered that this is equivalent to a group of 16 single frequency stations each separated by 2½ kilocycles. Future planning has caused the incorporation into new equipment of 8 additional pulse rates. When judiciously employed in a system of geographical separation designed to avoid a nuisance condition which might be brought about by having too many signals of comparable magnitude at any one world location the future Loran systems will make possible the operation of 24 pulse rates on one radio channel or the equivalent of 1.67 kc separation of single frequency type radio facilities in any one area of the world.

LORAN FOR SMALL CRAFT AND FOR MEDIUM DISTANCE NAVIGATION

16. At the conclusion of the war Loran was released for use by merchant ships primarily with the view that it would be used at long distances, to supplement the use of radiobeacon and shipboard direction finders. Somewhat surprisingly Loran equipment has been purchased and installed on small fishing ships of the trawler class which are only about 100 feet long. It is reported that shortly after installation it has been found that a typical trawler can save considerable time and money in locating the desired fishing ground or bank by use of Loran. A 3-line fix in less than 5 minutes is common practice. Loran is also used to determine the position when the net is set out and again when the net is hauled back about an hour or two later, to give the distance traveled and to keep on the best fishing ground. Loran on fishermen has been useful in avoiding damage to nets and other equipment. These

results have been obtained in the North Atlantic but as a result of this experience the trials have spread to the Pacific fishing fleets. Most of these fishing ship installations use the simple direct-reading type of Loran indicator which requires very little training. One fishing trawler captain sums up his operational trial experience by saying that Loran is the best thing invented since the depth finder. Since the cost of Loran equipment is not greatly different from that of a good quality radio direction finder and since it is not in any way dependent on the accuracy of the ship's compass or on calibration with respect to the entire ship structure, both of which are considerable economic factors in the use of the shipboard radio direction finders, it now appears that the small fishing boat or yachtsman may find considerable overall saving in time and money by using Loran.

17. At the London IMRAMN some questions were asked about the use of Loran for medium distance navigation and at that time the U. S. delegation did not suggest Loran as a substitute for the widely used radiobeacon system. During the ensuing months a considerable number of new postwar radars have been installed on merchant ships and considerable additional experience has been had with Loran for peacetime navigation purposes. In very general summary it has been found that the new merchant ship radars are observing large sea buoys at 6 or 8 miles and can use powered radar beacons at 10 or 15 miles quite readily. On the other hand Loran has been used for coastal navigation at much closer inshore distances than was expected. This has raised the interesting conjecture that possibly radar, with some elementary radar beacons and supplemented by Loran, could provide a complete system for marine navigators. An illustration of Loran for medium distance navigation will be provided to you out of New London next week where Loran charts with 2 microsecond chart lines will be furnished for your own use and trial. The survey party which made the trials out of New London preparatory to the forthcoming demonstration commented that "Loran has not been properly exploited as a pilot aid". You will be able to form your own opinion of the use of Loran, Radar and Radar-aids as a complete system during forthcoming demonstrations.

18. You may wonder why Loran service is just recently being operationally tried for medium distance navigation. The chief reasons are (a) the use of automatic synchronization at the ground stations which seems to provide service good to about 1 microsecond accuracy as against 2 microseconds for manual synchronization and (b) the development of ground station system engineering techniques which permit a systematic removal of several small system errors which existed in some of the original wartime installations and resulted in disagreements between charts and actual service of 3 or 4 microseconds in certain sectors of some Loran service areas. Standard procedures for these techniques have now been put into general practice and thereby permit

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
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IMPROVEMENTS IN LORAN EQUIPMENT FOR SHIPBORNE USE

- By -

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ABSTRACT

Several Loran equipments for shipborne and airborne use were described at the International Meeting on Radio Aids to Marine Navigation in London in 1946. Improvements made, since that time, consist of, (a) modifications to the equipments previously described, (b) the development and production of a new receiver indicator and, (c) developments successfully past the laboratory stage but not yet in production.

These improvements are briefly discussed. A view of future development to make use of possible extension of the Standard Loran System is presented.

IMPROVEMENTS IN LORAN EQUIPMENT FOR SHIPBORNE USE

Introductory

1. The Loran equipments for shipborne use described at the International Meeting on Radio Aids to Marine Navigation in 1946 were the DAS-3, the AN/APN-4 and the AN/APN-9.[1] The DAS-3 was especially designed for shipborne use. The latter two equipments were designed for airborne use but, of course, could be employed on board ships with the addition of suitable power supply conversion apparatus.

2. This paper proposes to discuss, (a) the improvements, in the nature of modifications, made to the above equipment, (b) completely new equipment being produced and, (c) developments successfully past the laboratory stage and which have materialized as working models. A brief discussion of what now appears to be the trend of future improvements is also presented.

The Function of Shipborne Loran Equipment

3. The function of the equipment installed on board ship is simply the measurement of the difference in time of arrival of pulses from a pair, or a number of pairs, of time-synchronized Loran transmitters. The Loran System remains the same as that described at the last meeting.[2] Therefore no additional or different tasks are required of the shipborne sets.

4. The DAS-3 performs its functions satisfactorily. However, certain improvements were suggested by operating personnel in order to simplify the operating procedure used to obtain a Loran reading. The arrangement of controls and some of the panel markings were found to be not entirely desirable. The AN/APN-4 was originally designed for airborne use as was the AN/APN-9. Consequently effort was made to reduce size and weight. The panel controls were simple, both in arrangement and number, compared with early shipborne units.

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1. International Meeting on Radio Aids to Marine Navigation, May 1946, Volume II Radio Navigation, Radar and Position Fixing Systems for use in Marine Navigation; London; His Majesty's Stationery Office 1946; p. 43.

2. Ibid: pp 41-45

5. The display on the cathode ray tube of the AN/APN-9 is different than that on either of the other two equipments and will be discussed later. All three, however, are similar in that the two signal pulse envelopes are matched or superimposed by the introduction of delay in the circuit producing one of the traces. The measurement of the delay introduced, equal to the difference in the times of arrival of the two signals, is accomplished by counting one or more sets of calibration markers. This latter procedure has been cited as a disadvantage of pulse systems,[1] although it is actually only a characteristic of these equipments.

Modifications Made to Above Equipments

6. Only minor modifications have been made to the DAS series. These consist mainly of the addition of a control for allowing the reception of eight more specific pulse repetition rates (Basic S) and another to allow more accurate reading of the time difference.

7. The original AN/APN-9 design has been modified to some considerable extent for marine use and is now offered for sale by the Radiomarine Corporation of America as the LR-8801. A new mounting frame (shown in Figure 1) is provided. Installation of the set in restricted locations on board ship is easily accomplished as the frame allows both horizontal or near vertical mounting. The power supply was changed for operation on a 115 volt, 60 cycle source. An additional control, concentric with the "fine delay" control provides vernier adjustment of delay and thus allows close matching of the pulse envelopes. The dimensions of the equipment are, approximately, 13 1/2 inches wide, 14 inches high and 26 inches in depth. The total weight is 89 pounds. The panel controls, as shown in Figure 1, allow fast setting up of the station rate. All functions required for matching and reading are controlled by one knob. Other operating controls are conveniently placed. There are a total of thirty-five tubes employed, including the three-inch cathode ray tube. The latter is provided with a magnifying lens housed in visor which also serves to exclude light. Four radio frequency channels, and sixteen pulse repetition rates (Basic L and H) are selected by panel controls. The display on the cathode ray tube is different than that of other shipborne equipments in that a semi-logarithmic sweep is used. This feature is viewed as an improvement by some operators as the

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1. Loc. cit. art. 10.5.3 p 40

pulse is apparently expanded or stretched by merely moving it to the left hand end of the trace. Other operators, perhaps those accustomed to linear sweep display, find difficulty in interpreting sky wave pulses. Therefore it appears to be a matter of personal preference as to the relative advantages and disadvantages of the two forms of display. Figure 2 shows the internal arrangement of components.

New Loran Shipborne Equipment

8. A completely new Loran receiver indicator, designed for marine use, is the Sperry MARK I, Mod. 1, manufactured by the Sperry Gyroscope Company. Originally designed for the U. S. Navy, the development was completed and manufacture begun before the end of the war. The equipment is housed in a cabinet constructed for deck mounting (Figure 3). The cathode ray tube is deeply recessed to allow operation in brightly lighted sites without the use of a visor or hood. The arrangement of components, as shown in Figure 4, allows replacement of complete subassemblies and provides easy access for servicing. Controls, other than those required for operation, are located under the front cover, thus allowing convenient access when required but at the same time discouraging accidental derangement and tampering. All essential operating controls are conveniently grouped on the top panel as shown in Figure 5. The "test" knob performs a very important function in that it allows the navigator to quickly perform all necessary tests to ascertain correct operation without the use of external equipment or even removing the front cover. A diagram illustrating the display on the cathode ray tube for the various test positions is placed under the top cover (Figure 3).

9. The outstanding feature of the Sperry MKI, Mod.1 is the direct reading counter, designed to eliminate the fore-mentioned disadvantage of calibration marker counting. Pulses are matched in the usual manner. As the delay knobs are turned, a counter mechanism similar to the mileage totalizer on an automobile speedometer indicates the delay in microseconds. The counting process is thereby eliminated as the time difference is merely read from the meter. The accuracy of the device is stated as plus or minus one-half microsecond and can be quickly checked with the use of the test switch mentioned above. A brief discussion of the relative accuracy of direct versus indirect reading indicators may be of interest. The process involved in

matching the pulse envelopes is similar for all sets and the same can be said of the alignment accuracy. The accuracy of reading the time difference when using indirect reading indicators depends upon the ability of the operator to estimate the distance from some reference marker to the nearest ten microsecond marker, thus performing a visual interpolation. The direct reading device utilizes a mechanical counter for interpolation. A test position is provided to check the accuracy of the setting of the counter at ten microsecond intervals by superimposition of markers. A comparison of the two systems shows that for the direct reading device the overall accuracy depends upon the ability of the operator to match pulse envelopes by superimposition of the traces, while for the other device, the overall accuracy depends upon the pulse matching ability together with the ability to interpolate between markers.

10. The equipment described above is capable of receiving signals transmitted on the four Loran radio frequency channels and on twenty-four specific pulse repetition rates (Basic H, L and S). Its direct reading feature enables it to make full use of the basic accuracy of the Loran system, shortens the time required for obtaining a fix and reduces to an appreciable extent human errors in obtaining the measurements.

Developments Being Undertaken at Present

11. The elimination of marker counting from the operating procedure has been accomplished by the direct reading Loran receiver indicator described above. Further advances can be directed toward the construction of smaller, simpler and cheaper equipments. Work is now being undertaken by several manufacturers toward this objective. Investigation has already indicated that size, weight and power supply requirements can be materially reduced, primarily by the use of miniature tubes. The Philco Corporation of Philadelphia has developed a new receiver indicator. Production has not yet begun; however, the laboratory work is reported to be complete.

12. This equipment is a direct reading instrument incorporating several new features aimed at reducing time required to obtain a fix. Two mechanical counters are available for recording the time difference reading on two pulse repetition rates. The operator is thereby permitted to make a reading on

one rate, using one counter mechanism. Then, after switching to the other rate, the other counter is used for the second reading. The first reading can be quickly checked by merely switching back to the first rate. The use of the double counter device shortens the interval between the two readings and may eliminate the necessity for advancing the first line by the distance the vessel has traveled during the interval. This feature is perhaps more attractive to aircraft users than to marine navigators.

13. Another new feature is the inclusion of an automatic frequency control which eliminates the manual phasing of the local oscillator with the incoming signal. This feature is necessary to take full advantage of the dual counters as, otherwise, the "drift" control would normally require slight readjustment each time the set is switched to another rate.

14. By making use of miniature tubes, space, weight and power drain are materially reduced. The size of the complete unit is only 15 inches by 15 inches by 10 inches. Although the above considerations are also of greater interest to aircraft users, certain marine installation problems, particularly on small vessels, are simplified. Full coverage of the Standard Loran System, including the four radio frequency channels and twenty-four specific pulse repetition rates, is provided. In addition, the receiver may be tuned to two channels in the 180 to 220 kilocycle band being investigated at this time.

15. Lest users of existing Loran receiver indicators fear possible obsolescence of their equipment should the low frequency channels come into general use, it should be emphasized that the existing receivers would require merely the addition of a small box containing frequency conversion circuits for the reception of the low frequency signals.

Possible Trends of Future Developments

16. Extensive simplification of Loran receiver indicators by the use of trick "tube saving" circuits does not appear to be possible for the immediate future. The successful development of a direct reading instrument has been a great step toward simplifying operating procedure. The next step is, obviously, the development of automatic, instantaneous, and continuous indication of the time difference on one or more pulse repetition

rates. The practical benefits of such a device for marine use are questionable in view of necessary added circuit complications with attendant maintenance difficulties. One of the outstanding features of the pulse technique is the ability to discriminate, visually, between multiple path pulses. To do so with the use of automatically operated circuits indeed presents a problem. Further refinement, such as matching individual cycles of the radio frequency signal rather than the matching of pulse envelopes would result in accuracies comparable with phase matching systems, without the inherent disadvantage of lane ambiguity present with the latter system.

17. We must realize, however, that it may be some time before any greatly improved system can be developed and its attendant "growing pains" ameliorated. From the practical point of view of both the navigator and of the manufacturer of equipment, waiting for the materialization of ideas is always a lengthy and costly proceeding. In the meantime, the currently available instruments for shipborne use, together with the existing, time-proven, Standard Loran System, offer the navigator a practical, useful means for solving much of his problem.

18. To potential users, who anxiously await promises of reduced costs, a simple analysis should show that development, engineering, and tooling costs must be absorbed by the total number of units manufactured and it therefore follows that general acceptance of the systems allows quantity production which, in turn, means lower unit costs.

19. Loran receiver indicators currently offered for sale fulfill a definite need in aiding long range navigation in a thoroughly practical and dependable manner. Much of the development and engineering cost has already been liquidated. General acceptance of current models therefore has obvious advantages.

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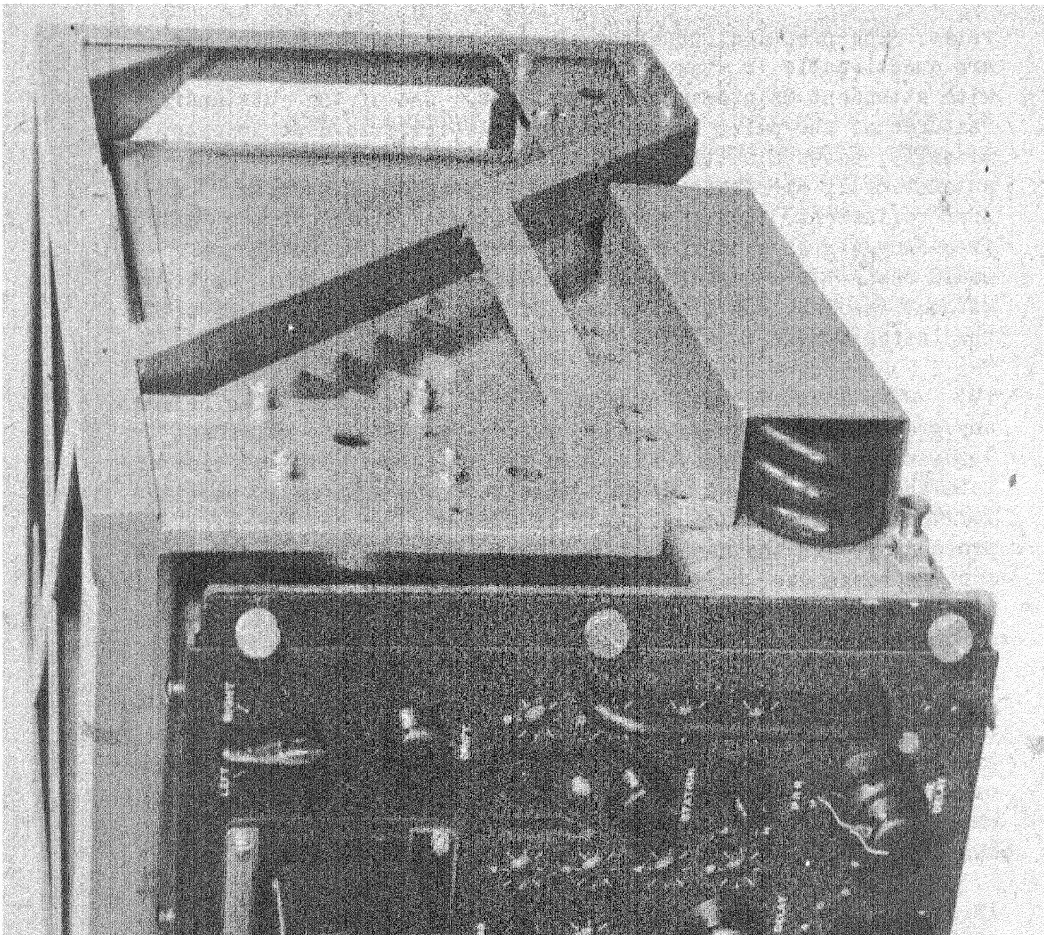

Figure 1: RADIOMARINE MODEL LR-8801

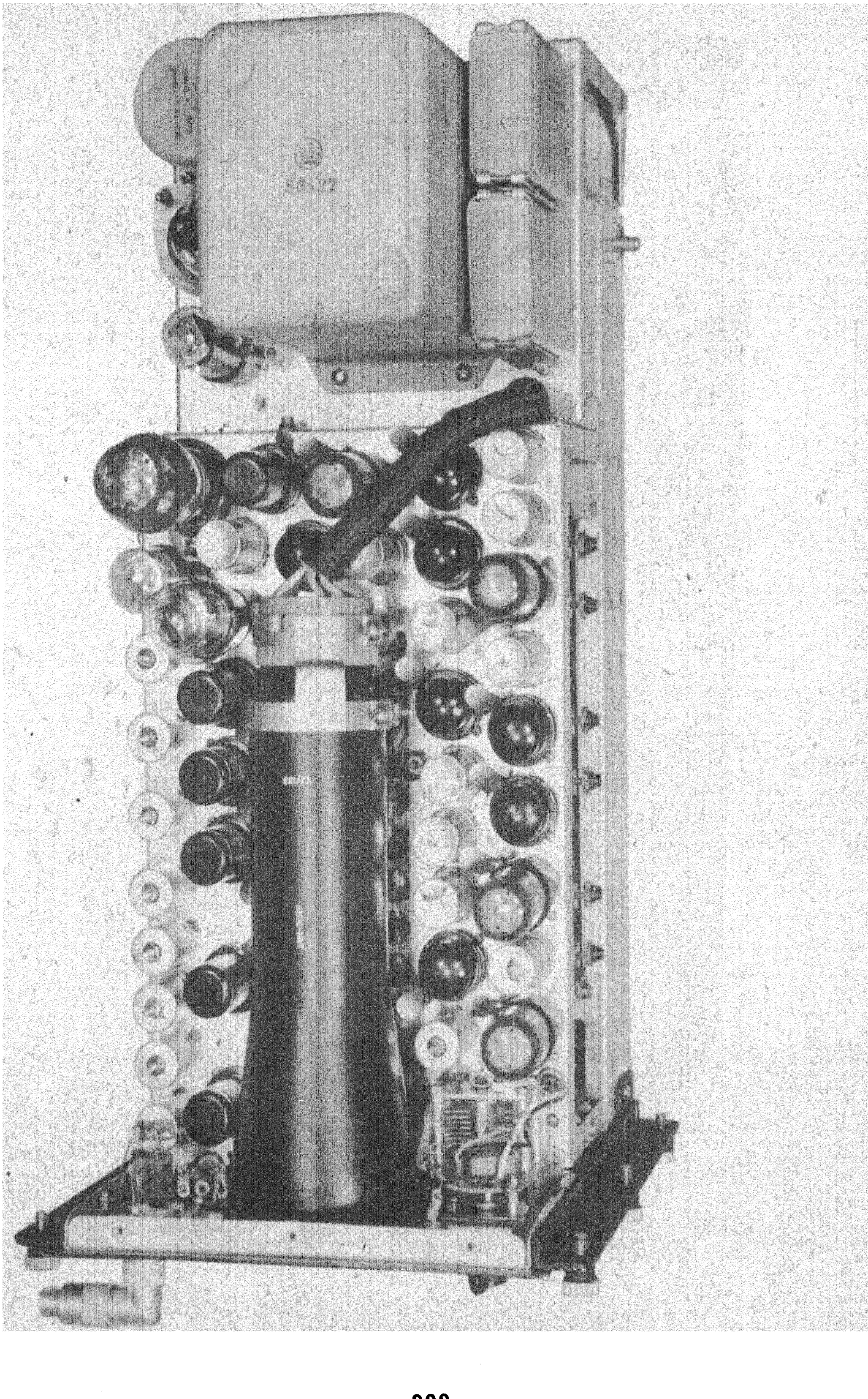

Figure 2: RADIOMARINE MODEL LR-8801

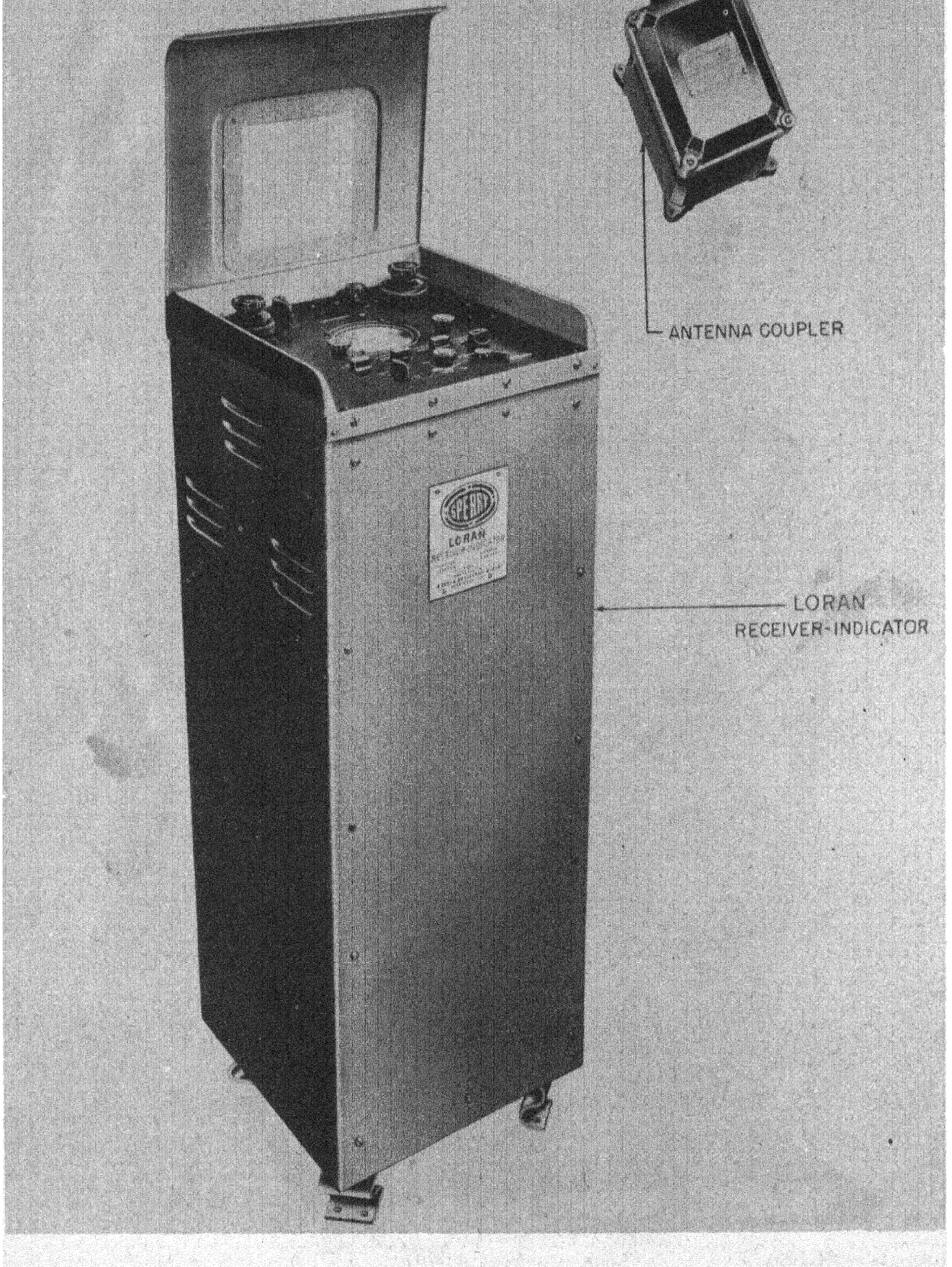

Figure 3: SPERRY MK.I, Mod.1

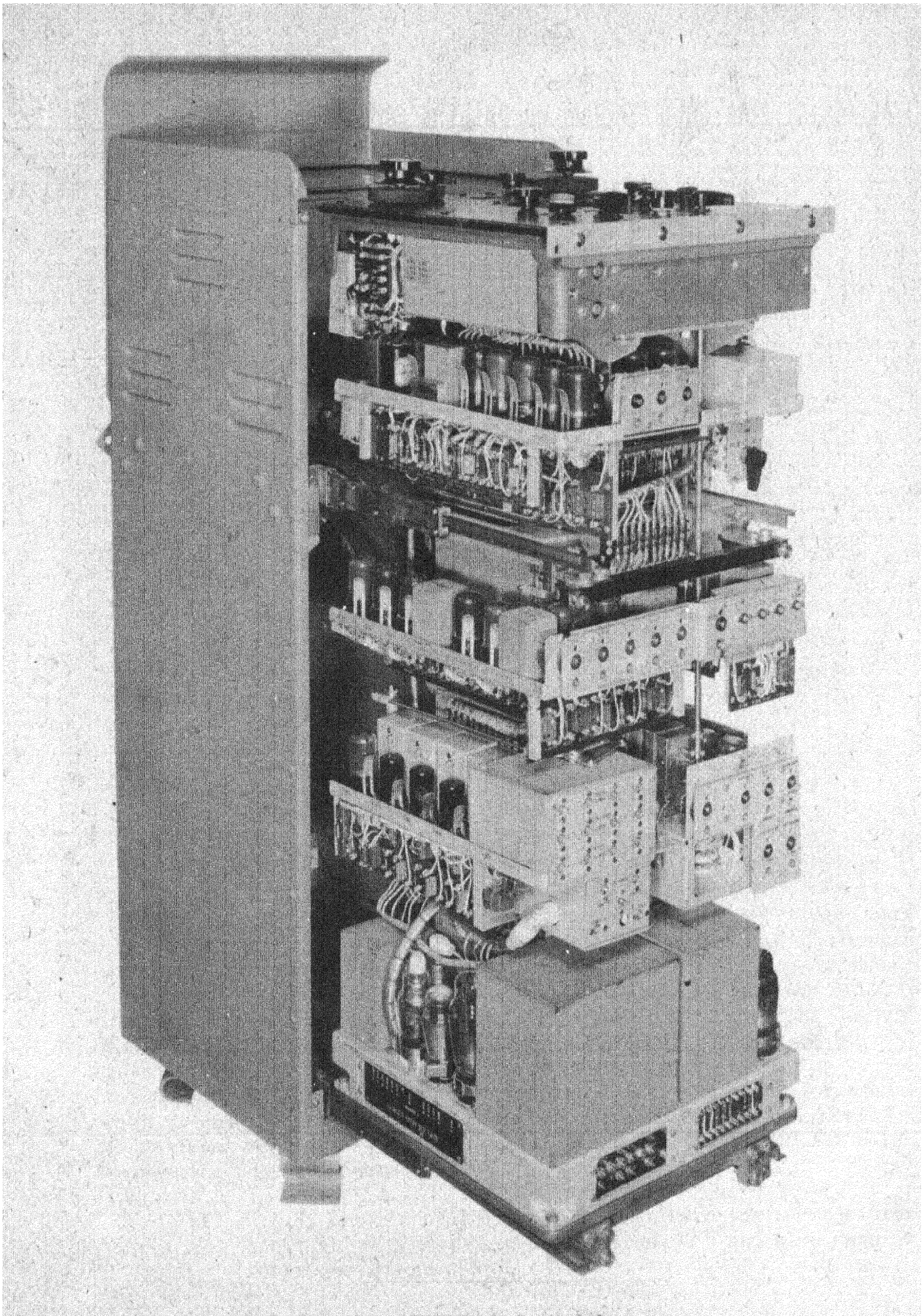

Figure 4: SPERRY MK.I, Mod.1

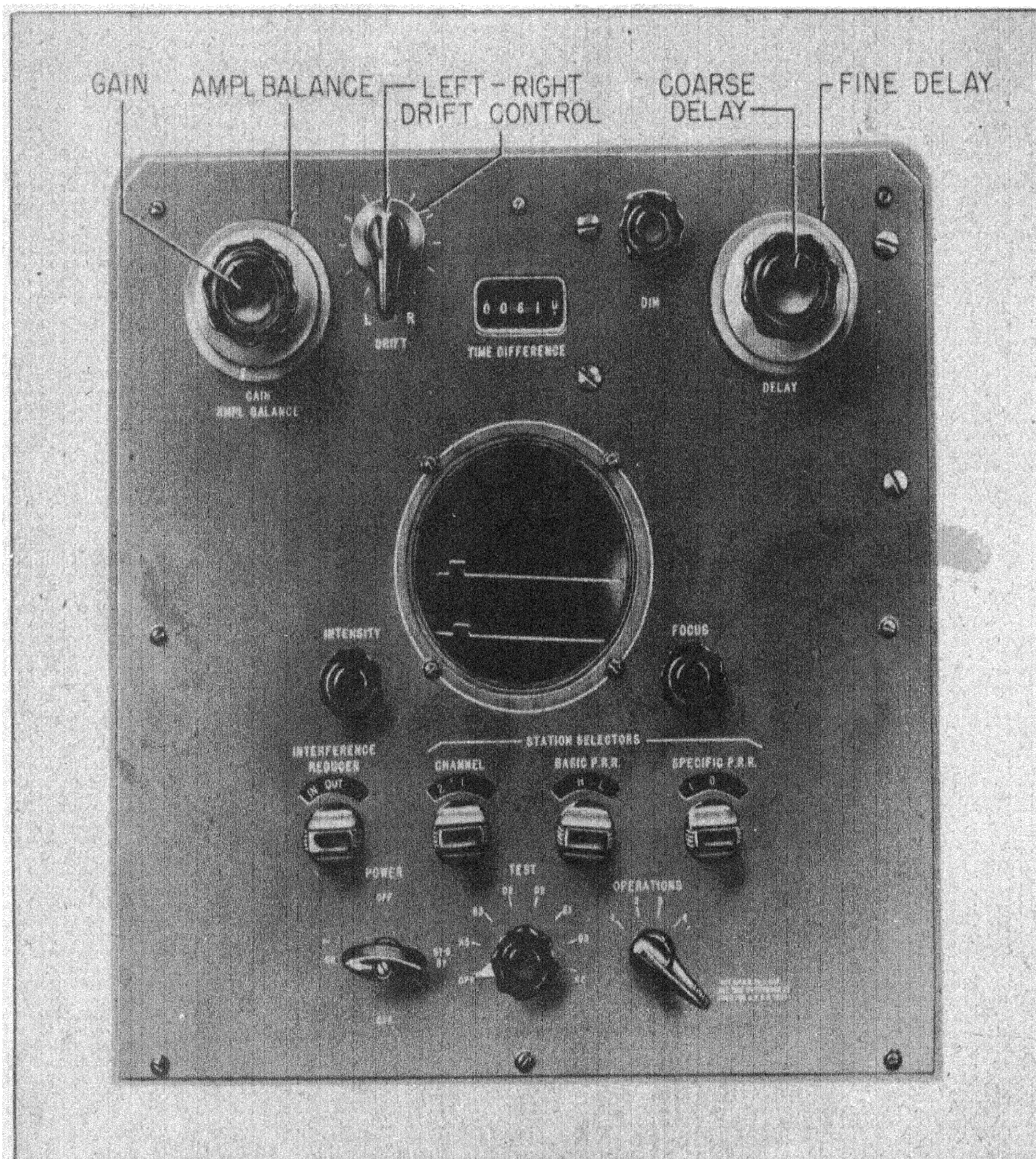

Figure 5: SPERRY MK.I, Mod.1

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
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CONSOL.

INTRODUCTION

1. The Consol Navigation System (a British improvement of the German Sonne System) was described at first I.M.R.A.M.N. (Vol. II of report, page 32) and estimated performance figures were quoted. At that time three Sonne stations were in operation, at Stavanger (Norway), Lugo and Seville (Spain), operating on frequencies of 319, 303, and 311 Kc/s respectively. Since than a Consol station using British equipment has been brought into continuous operation at Bush Mills in Northern Ireland on a frequency of 263 Kc/s. The establishment of this service was announced in an Admiralty Notice to Mariners on 29th October, 1946, and has made possible operational trials on ships in order to obtain some estimate of the usefulness of the system for Marine Navigation. Investigations of the accuracy of the system have continued.

PART I - MARINE USER TRIALS

Scope of Trials

2. The Bush Mills and Stavanger stations together provide good facilities for fixing position over part of the North Atlantic and the seas around Great Britain, and comprehensive trials have been carried out in these areas; further trials are still in progress. The signals can be received on the medium frequency communications receiver which is standard equipment on most ships, and an observation merely involves counting dots and dashes. The ships selected to report on the Consol system have been supplied with instructions describing the system, hints on the best method of making a dot/dash count, charts for transforming dot/dash counts into position lines, and blank forms on which to enter Consol fixes against the position obtained by normal navigational methods. Two fairly small scale charts, issued for Air Navigation purposes, were used:-

(1) R.A.F. Experimental Consol Chart on Mercator's Projection, scale 1:2,000,000, between latitude 50°N and 61°N, and Longitude 1°W and 30°W.

(2) Topographical Consol Chart, Great Britain, Sheet 2, scale

1:1,000,000 (Conical Orthomorphic Projection).

The projection used for the second is not very suitable for marine navigation, but one of the main purposes of the investigation was to determine whether the reception accorded the Consol system warranted the Production of special charts for marine users.

3. Up to the present the ships participating in these trials have included:-

- 28 deep-sea and coastal vessels (passenger and general cargo);
- 3 colliers;
- 3 ships engaged in special duties.

In addition, similar trials are being carried out in the Royal Navy, from which reports have also been received.

4. Ships captains were asked to give their opinion on the value of the system, the ease of obtaining fixes, and the nature and degree of any interference. In addition the logs of Consol fixes against navigational positions were also required.

<u>General Considerations</u>

5. While there were expectations that mariners would regard Consol as a useful aid when it was not possible to obtain a fix by other means, e.g. D/F bearings, the opinions so far expressed indicate that it has wider possibilities. It appears that ships officers consider Consol to have certain technical advantages over ordinary D/F. They have stressed that without doubt Consol will prove to be a valuable aid to navigation. These conclusions have been reached although severe interference has been experienced during the trials, particularly from beacons on or very near the Bush Mills frequency.

6. The process of obtaining a position is simple and little practice is needed to recognise and count the characters correctly. Up to the present the main handicap has been the absence of tables (of Consol readings against geographical position) or suitable marine charts. See U.K. Paper No. 19.

7. Various opinions have been expressed on the rate of transmission, since Bush Mills is twice as fast as Stavanger. The cycle of the German-built beacon at Stavanger (319 Kc/s) occupies two minutes,

of which the dot/dash period takes up one minute. At Bush Mills (263 Kc/s) the cycle has been reduced to 60 seconds, half of which is devoted to the dot/dash period. Although the Stavanger transmission is unduly slow, most navigators prefer it because it is easier to read. The Bush Mills speed is, in the words of one report, "as fast as can be conveniently used in practice when the highest accuracy is required". Nevertheless, there is some advantage in the higher speed, as two counts can be made in the time of one. Steps are now being taken to reduce the duration of the Bush Mills cycle still further to 40 seconds, but without increasing the speed of the count. If Stavenger were also to use this shorter cycle it should be possible to obtain a fix in two minutes or less.

8. The time ratio of dash to dot is also being considered. It appears that, as at present adjusted, the Bush Mills ratio of 3:1 is too low and navigating officers have some difficulty in distinguishing dots from dashes, and would like it increased to 5:1 as on the Stavanger transmissions.

9. It will be noticed that these considerations relate to matters that can be remedied without difficulty, and are of a type that may be anticipated in the initial stages of a practical investigation.

Comparison of Consol Fixes With Normal Navigational Fixes

10. The logs received from ships give Consol fixes obtained by ships officers in the course of their ordinary duties, against positions estimated by dead reckoning, buoy positions, visual bearings, etc. The figures are being analysed to obtain some estimate of the magnitude and distribution of errors. The figures that are so far available show that in the Irish Sea, (the centre of which may be taken as roughly 100 miles from Bush Mills and 450 miles from Stavanger), the standard deviation for fixes taken at night (the worst time) was 3.25 nautical miles; and in the southern part of the North Sea (approximately 260 miles from Bush Mills and 370 miles from Stavanger) the standard deviation by day was about 5.0 miles. These figures are likely to be on the high side because the estimated positions may themselves have been in error.

11. No mention of the lobe ambiquity of the system has been made by Mariners, since approximate positions have been known to within limits that positively established which of the six alternative bearing lines from each station a shop was on. It has not therefore been necessary for Mariners to take rought bearings of the ground stations with a D/F loop. (See report of 1st I.M.R.A.M.N. Vol. II, P.33).

Comparison With Shop-borne Direction Finding

12. Both Consol and M.F. D/F are systems giving a fix by bearings

from two stations, and a comparison between their performances is possible.

13. It is felt that there has been a tendency to over-estimate the accuracy of D/F; ship-borne D/F is very inaccurate at night at ranges above say 40 miles. Moreover, apart from any inaccuracies introduced by propagational phenomena several other factors usually affect the determination of a position line by D/F, e.g. errors the ships compass, error in D/F calibration, and lack of simultaneity in reading the ship's head and the D/F bearing. In clear weather the long periods that elapse between transmissions mean that 15 minutes or more may be required to obtain a D/F fix, and even when beacons operate on a fog schedule the time is likely to exceed six minutes.

14. The Consol system has these advantages

(i) No special equipment is needed; a ships ordinary communication receiver is sufficient.

(ii) No calibration of the receiving installations is involved.

(iii) No training is needed, simple written instructions are sufficient.

(iv) A medium frequency receiver fitted in a lifeboat could be used to determine position if Consol charts were carried.

(v) The signals occupy only very narrow bands, and cause little interference in comparison with M.C.W. (and pulse systems).

(vi) A few Consol stations cover an extensive area (Range 1,000 miles by day, 1,500 by night).

15. It is considered that M.F. D/F will remain as an established service for coastal navigation for some years, and should be improved; nevertheless consideration is being given to the possibility and practicability of a few Consol stations replacing a larger number of D/F beacons and giving higher accuracy and at least the same coverage.

Interim Conclusions

16. In the user trials already completed the Consol system is very favourably regarded by the mariner as an aid to navigation, particularly on ocean passages, because of its simplicity and independence of special receiving apparatus. The possibility of using the system to give assistance in coastal navigation should be considered.

PART 2. ACCURACY INVESTIGATIONS

17. Having described the steps that are being taken to subject the Consol System to practical trials by the merchant marine and the first results of these trials, it may be of interest to survey the scientific work that has been (or is being) carried out to ascertain the accuracy of the system under various conditions.

18. The accuracy by day is governed by instrumental errors in the transmitting equipment including errors in the setting up of the correct phases and amplitudes of the currents in the aerials, and by irregularities in the surrounding terrain. Propogation is almost entirely by ground wave and such errors as have been observed during the day may be attributed to the above causes, rather than to the presence of ionospheric waves. At night, however, ionospheric waves appear, and have amplitudes which may be equal to, greater than or less than the amplitude of the ground wave, depending upon the location of the observer with respect to the transmitting station. Combinations of ground and ionospheric waves will, in general, give rise to bearing errors.

Theoretical Considerations

19. At very long ranges the polar pattern of the Consol aerial system corresponding to radiation reflected from the ionosphere is substantially the same as that for the ground wave. As the range is reduced, the two patterns differ materially. At night three regions will exist:-

(a) a region at long range in which the ionospheric wave will predominate

(b) a region nearer to the transmitting station in which ionospheric and ground waves have comparable magnitudes

(c) a region still closer to the transmitting station in which the ground wave predominates.

20. In region (a) the bearings obtained will be very nearly the same as those computed from the ground wave poler diagram. The error will however increase as the range decreases and can be computed with fair accuracy provided that only one ionospheric wave is present and that this wave does not deviate from the great circle path through the transmitting and receiving stations. In region (b) ground and ionospheric waves may combine in many ways and bearing errors may be large. In region (c) the accuracy will be limited by instrumental errors and irregularities in terrain.

21. Considering first region (a), in which it will be assured that a single ionospheric wave only is present, the bearing error is

small and is given approximately by:

$$\Delta\theta = (1 - \cos\alpha) \quad \tan\theta \quad (1)$$

where θ is the bearing referred to the normal to the line of aerials and α is the angle of elevation of the ionospheric wave at the earth's surface. This is a systematic error which gives an apparent bearing too close to the normal to the line of aerials. Assuming normal E- layer reflection at height of 90 kms., $\Delta\theta$ may vary with range and azimuth, as indicated in Fig. 1. As the range is reduced, equation (1) is no longer valid, and, in the limit, the systematic error may be negligible. Since ground and ionospheric waves have comparable magnitudes at a range of about 370 miles for an overseas path, the error curves may be expected to have maxima at this range for any azimuth. The maxima are likely to occur between 250 and 300 miles for an overland path.

22. At extremely short and long ranges, the random errors are likely to be fairly small. At intermediate ranges, however, ground and ionospheric waves combine with random phase, and probably with random relative amplitudes . Random errors will therefore be superimposed upon the systematic error generally as shown in Fig. 2.

23. The effect of random combination of the ground and ionospheric waves may be visualised as the opening and closing of the polar pattern of the aerial system in a manner similar to the opening and closing of a fan. If the changes in the phase and amplitude of the ionospheric wave are sufficiently rapid and sufficiently great, an equi-signal might be heard twice or more during a keying cycle. Such counts would of course be meaningless, and should be disregarded. If, however, the change of phase and amplitude of the ionospheric wave is slow an equi-signal will be heard once only, but an incorrect count of the radiated Morse characters may result.

24. The above qualitative analysis has been confined to the case of a signle ionospheric wave. But should multiple ionospheric waves appear, as is quite likely at long ranges, subsidiary maxima may occur in the error curves.

<u>Summary of Observations over Sea</u>

25. Fig. 6 shows the results of an interesting series of observations made during three trips on the Glasgow - Montreal route. This route is substantially radial to Bush Mills and at approximately 20° to the normal. Other investigations carried out in the United Kingdom have been somewhat limited in scope. However, the results obtained up to date permit the following generalisations to be stated:-

<u>Day errors</u>

(a) Systematic errors during the day are absent or very small.

(b) Random errors in the count of characters are independent of azimuth and substantially independent of range. Observations of Bush Mills disclosed a 50 % error of about half a character corresponding to 0.11° near the normal and 0.22° at the edge of the coverage. Observations of Stavanger, however, disclosed a 50% error of the order of two characters corresponding to about 0.33° near the normal and 0.67° at the edge of the coverage. But it is known that there was difficulty in maintaining adequate monitoring at Stavanger at the time the observations were made, so that greater reliance may be placed on the results quoted for Bush Mills.

Night Errors

(a) Systematic error increases steadily at sunset, is a maximum at about midnight and decreases steadily to zero or a small quantity at sunrise.

(b) Systematic error increases with increase of azimuth referred to the normal.

(c) The R.M.S. amplitude of random errors varies with time and azimuth in a manner similar to that of systematic errors. The 50 per cent error for Stavanger varies from about 0.4 degrees in the vicinity of the normal to about 1 degree at 40 degrees to the normal. These errors are applicable to a range of about 400 miles and are not likely to be exceeded for smaller or greater ranges, unless multiple ionospheric waves are received. (These figures for 50 per cent error refer to reception at ground monitoring stations. Random errors are somewhat greater in an aircraft due to less favourable conditions. The 50 per cent error of one observer may be as much as twice that of another due to difference of ability).

(d) Accuracy at ranges of the order of 400 miles from the station varies markedly from night to night. Poor accuracy is characterised by occasional reception of more than one equi-signal and by fading during the keying cycle.

Summary of Observations over Land

26. Observations made entirely over land under favourable conditions and under British control have not been possible. The Germans, however, carried out large scale observations on "Sonne 12" near Warsaw in which forty-five receiving stations, spread uniformly over the coverage area, took part.

27. <u>Day Errors</u>. Accuracy by day appears to be much the same as that for oversea observations. Whereas, however, the accuracy seems practically independent of range for an oversea path, errors are increased by a factor lying between two and four at 500 miles range for an overland path.

28. <u>Night Errors</u>. As would be expected, night errors of propogation over land have the same trends as night errors for propogation over sea. The results of the German observations are summarised in Figs. 3 4 and 5 and refer to the greatest errors, which occur at about midnight.

APPENDIX

BUSH MILLS TRANSMITTER

The following brief notes on the transmitter are appended.

1. Two units, the power supply and transmitter unit of a standard R.A.F. transmitter, supply 1 Kw of output power to the aerials, which radiate 500 watts. Another unit of similar size contains the special Consol apparatus for the keying and phase shifting operations, and the monitoring panel. Frequency is crystal controlled.

2. The whole of the apparatus is duplicated as a standby and for ease of maintenance. Power supply is normally derived from the mains, but a Diesel generator can be started up if the mains fail.

3. The transmitter is shut down daily from 1500 hours to 1515 hours to change over transmitters and to deal with any faults (e.g. on the aerials) which can only be tackled on a complete shut down.

4. Monitoring is carried out visually and aurally. One monitor is 1.3° to the side of the centre line at a distance of 2.2. km. from the transmitter. The signal heard should be 5 dots, an equisignal, and 55 dashes. If the phasing is incorrect, a correction can be applied by means of a control on the monitoring panel.

5. In practice, substantially the only adjustment that has to be made is matching of the feeders should this be required due to weather changes. The matching units are motor driven and are controlled from the panel.

6. Two men are on duty per watch.

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FIGS 1 & 2

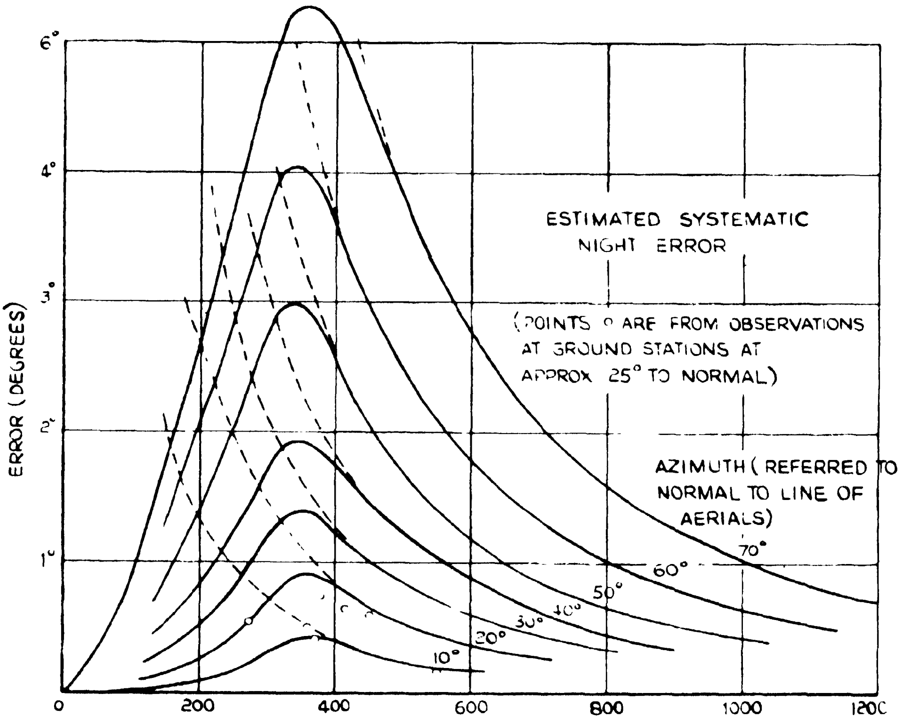


FIG. 1

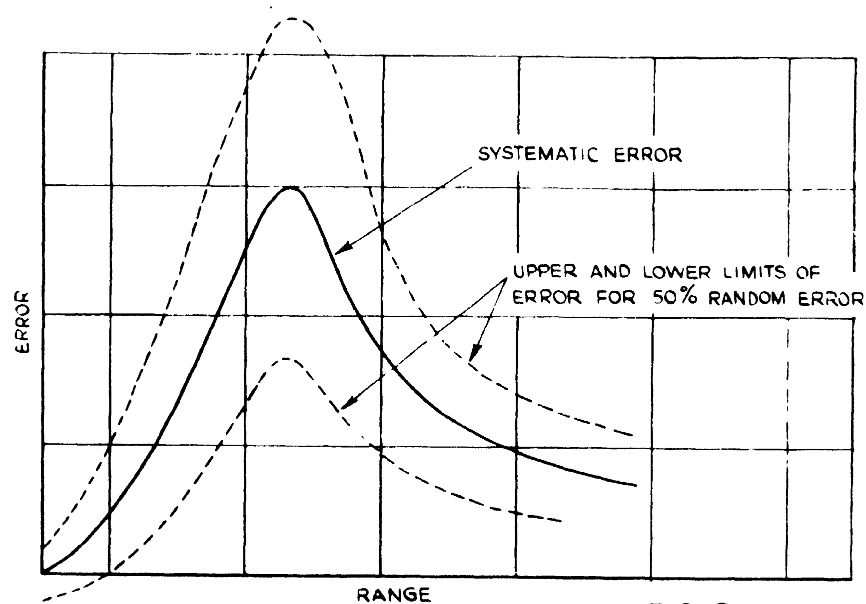


FIG. 2

CONSOL - SYSTEMATIC NIGHT ERRORS

FIG. 3

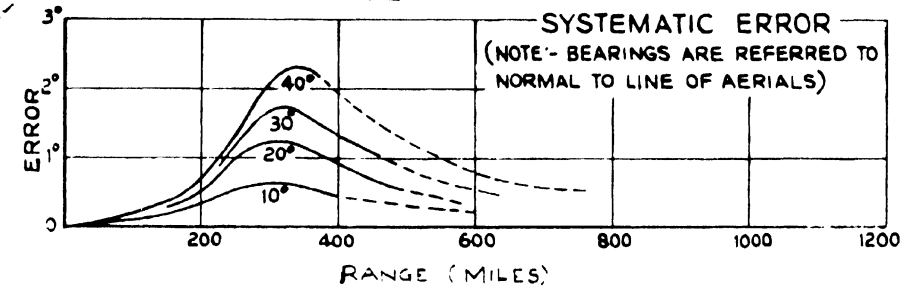


FIG. 4

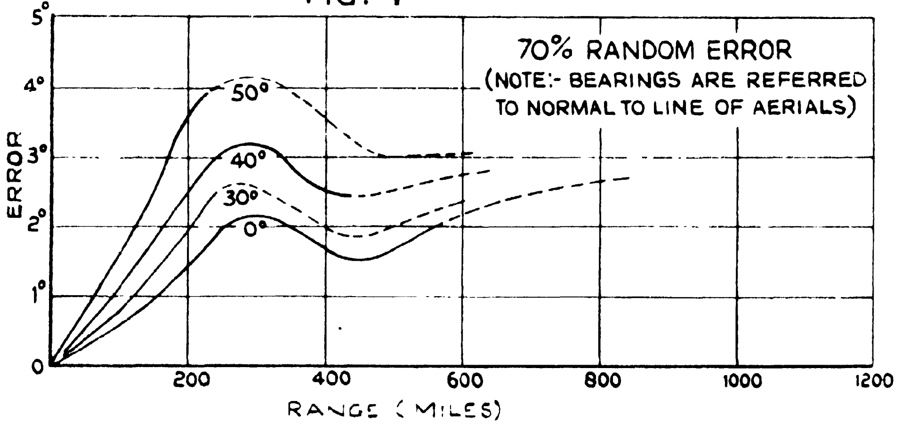
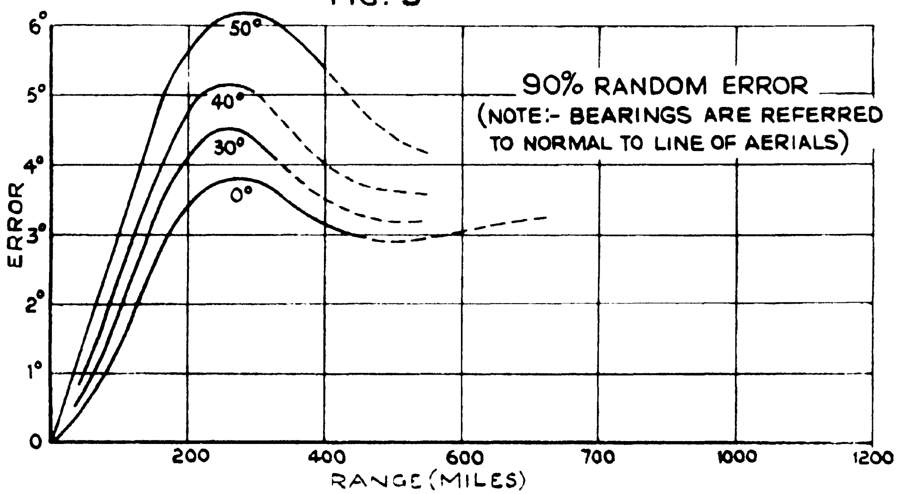
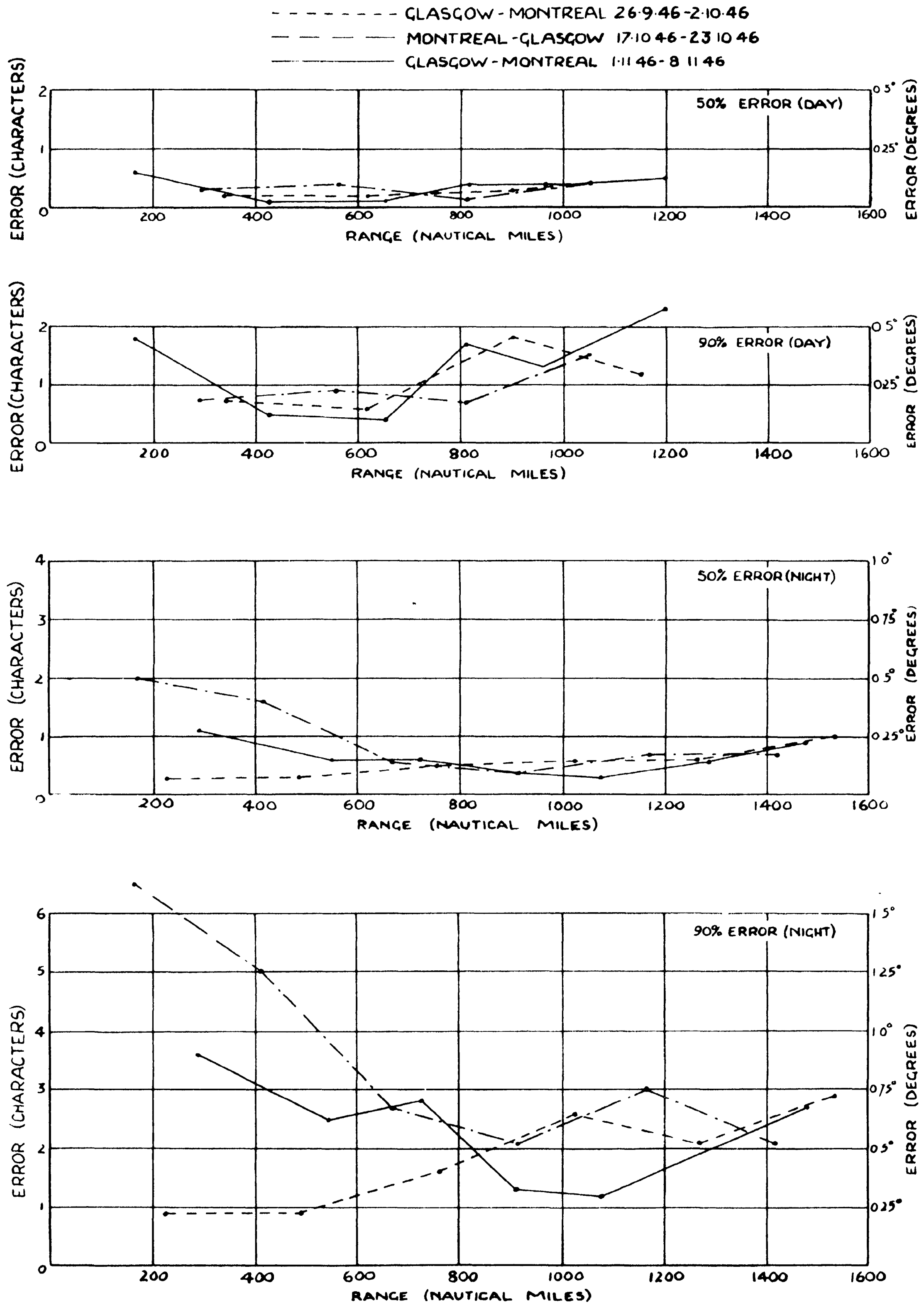


FIG. 5



CONSOL-OBSERVED SYSTEMATIC & RANDOM ERRORS (OBSERVATIONS AT NIGHT OVER LAND)



CONSOL – DAY & NIGHT RANDOM ERROR

IMMRAN DOC. 27

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN · · · APRIL 28-MAY 9, 1947

MARINE AIDS TO NAVIGATION BROADCASTS

- By -

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ABSTRACT

This paper describes in detail the methods and facilities used to inform ships at sea, of changes in aids to navigation and obstructions to navigation, by means of radio broadcasts. The proper manner for ship masters to report obstructions and defects in aids to navigation, which they observe, is also contained herein.

All United States Radio Stations which broadcast Hydrographic information and changes in aids to navigation are tabulated and appended as inclosures. The frequencies used and times of scheduled broadcast are indicated for each radio station.

MARINE AIDS TO NAVIGATION BROADCASTS

1. Of the many duties performed by the U. S. Coast Guard the three most closely related to the subject matter are (1) the maintenance of a system of marine aids to navigation, (2) the location and destruction of derelicts and other menaces to navigation, and (3) the International Ice Patrol.

2. The first, generally speaking, is local in nature and the broadcasts of outages, or changes in aids to navigation, are made by the local Coast Guard radio stations. The other two, on the other hand, are of interest to areas or sections and are broadcast from the large naval radio stations.

3. The United States, including the territories of Alaska and Hawaii, the Island of Puerto Rico and the Virgin Islands are divided geographically into fourteen Coast Guard districts. The district commander in each of these districts is responsible for the proper operation and maintenance of the marine aids to navigation in his district. In spite of all preventive measures, marine aids suffer casualties. It is the responsibility of the district commander to keep the mariner advised of any changes that take place in the established aids. Reports of outages are received from within the Coast Guard itself, from private citizens and, in many cases, from the master of a ship who becomes cognizant of the defect, from personal observation. The ship master is encouraged to report to the nearest Coast Guard district any defects as evidenced by the following notice which appears in several publications:

> "A report by radio of any defects noted in the aids to navigation in the waters of the United States and its possessions should be addressed "Coast Guard" and transmitted direct to one of the Government radio shore stations listed herein for relay to the Commander of the nearest Coast Guard District.
>
> Merchant ships may send messages relating to defects noted in aids to navigation through commercial facilities only when they are unable to contact a Government radio shore station. Charges for these messages will be paid by the U. S. Coast Guard.
>
> Such cooperation will assist materially in the prompt correction of defects, and in the effective maintenance of aids to navigation.
>
> Note:-- Most of the value of a report is lost by the delay which occurs when it is wrongly addressed."

4. From these reports the district commander and his staff prepare the material which is then transmitted to the radio stations within his district that are to broadcast this information. Each of the districts has its own radio facilities. At least one combined radio telegraph-radio telephone station is located in each district. In certain of the larger districts where a single station does not provide adequate coverage of the district, one or more additional combination radio stations are provided. In addition, certain Coast Guard depots and bases have been provided with radio telephone equipment only and broadcasts by voice are made from these stations. The broadcasts themselves are made twice each 24 hours. The complete broadcasts include weather which is furnished by the regional weather bureau office, any storm warnings which may be in force at the time,and the notice to mariners.

5. The regularly scheduled weather and marine information broadcasts by radio telegraph are preceded by preliminary announcement on the calling and distress frequency 500 kc two minutes prior to the scheduled time for the broadcast to begin. The actual broadcast is made on the working frequency assigned to the station. The radio telegraph broadcasts are sent clearly and distinctly, transmitted at a telegraphic speed not in excess of 15 words per minute. In most cases automatic tape is used for this purpose. As in the case of radio telegraph, the radio telephone broadcasts begin with preliminary announcement on 2670 kc, the frequency is then changed to 2698 kc and the report is read through once only at good writing speed and follows the natural phrasing of the text rather than word for word. The information contained in these broadcasts is also passed to the local coastal harbor radio station if there be one and is broadcast by that station on commercial frequency assigned to the station.

6. Storm warnings, advisory and other urgent marine information is broadcast immediately upon receipt and at each even or odd hour, as the case may be, for a period of 6 hours unless cancelled or superceded.

7. Reports received by the Coast Guard involving the more important changes or defects in the aids to navigation such as the displacement of the Nantucket Shoal Light Vessel or a serious obstruction in the approaches to a harbor are reported immediately to the Hydrographic Office of the Navy Department to be included in the broadcasts which are sent out daily by the Navy through its major radio stations.

8. Hydrographic information relating to western Atlantic waters is broadcast by Navy Radio Washington (NSS) in the Hydrolant series either numbered or unnumbered according to whether it is of general or of only local interest. In the Pacific waters a similar series known as Hydropacs is broadcast from Naval Radio Station Honolulu (NPM). Numbered Hydrolant and Hydropac messages are re-broadcast by all stations transmitting hydrographic information in their respective oceans. Unnumbered Hydrolant messages are re-broadcast only as necessary. Files of effective Hydrolants and Hydropacs are available at branch Hydrographic Offices, U. S. Navy Port Directors or from Collectors of Customs. The information broadcast by Coast Guard stations, which includes the weather and defects in local aids to navigation, is also available in printed form called Notice to Mariners which is issued by the Commander of each Coast Guard District and copies may be obtained from the nearest district office.

9. Ship masters should inform the Hydrographic Office immediately by radio of all derelicts, wreckage, mines or other floating obstructions to navigation. These reports should be addressed "Hydro" and transmitted direct to one of the Government radio shore stations listed herein.

10. These reports are compiled by the Hydrographic Office and issued as Hydrolants or Hydropacs as appropriate, and are broadcast by all stations covering the areas in which the obstructions to navigation are located.

11. When obstructions to navigation are removed or destroyed, this information is also broadcast.

12. One of the more important duties performed by the Coast Guard is that in connection with the International Ice Patrol, in accordance with the provisions of the International Convention for the Safety of Life at Sea, London 1929. The ice patrol is conducted by ships and planes assigned to this duty and operate under the Commander, International Ice Patrol. The object of the ice patrol service is to locate by scouting both by air and by surface craft, and from radio information obtained from passing ships, the location of icebergs and ice fields nearest to and menacing the North Atlantic steamship lanes. These patrols determine the southeastern, southern and southwestern limits of the ice areas in the general vicinity of the Grand Banks of Newfoundland. The patrols keep in touch with the ice as it moves southward in order that the trans-Atlantic shipping may be continually advised of the location of the ice.

13. The vessel on patrol uses the International radio call NIDK. When not actually on patrol it uses its own International call. These vessels maintain a continuous listening watch on

500 and 8280 kc for distress signals. A continuous watch is also maintained on 468 kc for general communication with vessels of the Merchant Marine.

14. The work of the cutters on patrol is greatly facilitated by reports which are transmitted to the Ice Patrol vessel by vessels of all nations which transverse the North Atlantic. The ships transversing this area are requested to furnish the following data by radio: (a) Iceberg or other object cited giving time (GCT), latitude, longitude, set, and drift; and in case it is an iceberg the temperature of surface water at the time should be included. (b) when bound east or west, report every four hours while between latitudes 39° North and 49° North, and between longitudes 43° West and 54° West, giving time of observation, latitude, longitude, course and speed, air temperature, visibility, surface temperature of sea water, wind, and sea conditions. These data facilitate the drawing of a temperature chart which is useful in locating the various currents and predicting the drift of icebergs.

15. The patrol vessel summarizes the reports received from other ships together with its own observations and transmits this information to the Commander of the International Ice Patrol. There it is analyzed and an ice bulletin is prepared. This bulletin is then broadcast by radio station Argentia, Newfoundland, radio call NWP. These broadcasts are made twice daily at 0118 and 1318 GCT. Each broadcast is preceded by the general call CQ on 500 kc with instructions to shift to receive on 480 kc A-2 emission and 8100 kc CW. After shifting to these frequencies, Station NWP transmits test signals and the International Ice Patrol call NIDK for 30 seconds to permit the ship's operator to adjust his receiver for best reception. The ice bulletin is then transmitted. At the conclusion of the first transmission and after an interval of 2 minutes the bulletin is again transmitted on both frequencies.

16. Special ice bulletins may be broadcast at times other than regular scheduled times if urgency warrants. In such cases a preliminary call will be made prior to transmission of special bulletin. The transmission of special bulletins because of their urgency will be preceded by the International Safety signal TTT. The ice bulletin is also transmitted to the Hydrographic Office in Washington, D. C. and re-broadcast by the large Navy radio stations.

17. Copies of this paper are available. Included are tabulations showing the radio stations that broadcast material as

outlined herein, indicating both the frequencies and the times of scheduled broadcasts.

E. K. RHODES
COMMANDER, U. S. COAST GUARD
ASST. CHIEF, COMMUNICATIONS DIVISION

INCLOSURE A

STATIONS BROADCASTING MARINE INFORMATION

STATION AND CALL LETTERS	TIME (G.C.T.)	FREQUENCY (KC.)	EMISSION	NATURE OF BROADCAST
ROCKLAND, MAINE (NUE)	1730	2698	A-3	REGULAR BROADCASTS
	UPON RECEIPT AND ON EVEN HOUR INTERVALS	2698	A-3	EMERGENCY BROADCASTS
BOSTON, MASS. (NMF)	0343 AND 1548	2698	A-3	REGULAR BROADCASTS
	0400 AND 1600	425	A-1	DO.
	UPON RECEIPT AND ON EVEN HOUR INTERVALS	425	A-1	EMERGENCY BROADCASTS
	UPON RECEIPT AND ON ODD HOUR INTERVALS	2698	A-3	DO.
NEW YORK, N.Y. (NMY-2)	0400 AND 1600	474	A-2	REGULAR BROADCASTS
	UPON RECEIPT AND ON EVEN HOUR INTERVALS	474	A-2	EMERGENCY BROADCASTS
NEW YORK, N.Y. (NMY)	0400 AND 1600	2698	A-3	REGULAR BROADCASTS
	UPON RECEIPT AND ON ODD HOUR INTERVALS	2698	A-3	EMERGENCY BROADCASTS
PHILADELPHIA, PA. (NMK)	0518 AND 1718	2698	A-3	REGULAR BROADCASTS
	0500 AND 1700	425	A-1	DO.
	UPON RECEIPT AND ON EVEN HOUR INTERVALS	2698	A-3	EMERGENCY BROADCASTS
	UPON RECEIPT AND ON ODD HOUR INTERVALS	425	A-1	DO.
BALTIMORE, MD. (NMN-7)	1748	2698	A-3	REGULAR BROADCASTS
	UPON RECEIPT AND ON ODD HOUR INTERVALS	2698	A-3	EMERGENCY BROADCASTS
NORFOLK, VA. (NMN)	0430 AND 1630	2698	A-3	REGULAR BROADCASTS
	0400 AND 1600	410	A-1	DO.
	UPON RECEIPT AND ON EVEN HOUR INTERVALS	410	A-1	EMERGENCY BROADCASTS
	DO.	2698	A-3	DO.
FORT MACON, N.C. (NMN-37)	1718	2698	A-3	REGULAR BROADCASTS
	UPON RECEIPT AND ON ODD HOUR INTERVALS	2698	A-3	EMERGENCY BROADCASTS

STATIONS BROADCASTING MARINE INFORMATION (CONT)

STATION AND CALL LETTERS	TIME (G.C.T.)	FREQUENCY (KC.)	EMISSION	NATURE OF BROADCASTS
CHARLESTON, S.C. (NMB)	0548 AND 1748	2698	A-3	REGULAR BROADCASTS
	UPON RECEIPT AND ON EVEN HOUR INTERVALS	2698	A-3	EMERGENCY BROADCASTS
JACKSONVILLE, FLA. (NMV)	0500 AND 1700	2698	A-3	REGULAR BROADCASTS
	UPON RECEIPT AND ON ODD HOUR INTERVALS	2698	A-3	EMERGENCY BROADCASTS
	DO.	464	A-1	DO.
MIAMI, FLA. (NMA)	0400 AND 1600	482	A-2	REGULAR BROADCASTS
	UPON RECEIPT AND ON EVEN HOUR INTERVALS	482	A-2	EMERGENCY BROADCASTS
KEY WEST, FLA. (NOK)	0413 AND 1618	2698	A-3	REGULAR BROADCASTS
	UPON RECEIPT AND ON EVEN HOUR INTERVALS	2698	A-3	EMERGENCY BROADCASTS
ST.PETERSBURG, FLA. (NOF)	0518 AND 1718	2698	A-3	REGULAR BROADCASTS
	UPON RECEIPT AND ON EVEN HOUR INTERVALS	2698	A-3	EMERGENCY BROADCASTS
MOBILE, ALA. (NOQ)	0530 AND 1730	2698	A-3	REGULAR BROADCASTS
	UPON RECEIPT AND ON ODD HOUR INTERVALS	464	A-1	EMERGENCY BROADCASTS
	UPON RECEIPT AND ON EVEN HOUR INTERVALS	2698	A-3	DO.
NEW ORLEANS, LA. (NMG)	0418 AND 1618	448	A-2	REGULAR BROADCASTS
	UPON RECEIPT AND ON EVEN HOUR INTERVALS	448	A-2	EMERGENCY BROADCASTS
GALVESTON, TEX. (NOY)	0400 AND 1600	2698	A-3	REGULAR BROADCASTS
	UPON RECEIPT AND ON EVEN HOUR INTERVALS	425	A-1	EMERGENCY BROADCASTS
	UPON RECEIPT AND ON ODD HOUR INTERVALS	2698	A-3	DO.
SAN JUAN, P.R. (NMR)	0300 AND 1500	2698	A-3	REGULAR BROADCASTS
	0330 AND 1530	127	A-1	DO.
	UPON RECEIPT AND ON EVEN HOUR INTERVALS	127	A-1	EMERGENCY BROADCASTS
	UPON RECEIPT AND ON ODD HOUR INTERVALS	2698	A-3	DO.

STATION AND CALL LETTERS	TIME (G.C.T.)	FRE-QUENCY (KC.)	EMIS-SION	NATURE OF BROADCAST
LONG BEACH, CALIF. (NMQ)	0400 AND 1600	425	A-1	REGULAR BROADCASTS
	0400 AND 1600	2698	A-3	DO.
	UPON RECEIPT AND ON ODD HOUR INTERVALS	2698	A-3	EMERGENCY BROADCASTS
	UPON RECEIPT AND ON EVEN HOUR INTERVALS	425	A-1	DO.
MONTEREY, CALIF. (NOJ)	0448 AND 1648	2698	A-3	REGULAR BROADCASTS
	UPON RECEIPT AND ON EVEN HOUR INTERVALS	2698	A-3	EMERGENCY BROADCASTS
SAN FRANCISCO, CALIF. (NMC-2)	0400 AND 1600	418	A-2	REGULAR BROADCASTS
	UPON RECEIPT AND ON EVEN HOUR INTERVALS	418	A-2	EMERGENCY BROADCASTS
SAN FRANCISCO, CALIF. (NMC)	0418 AND 1618	2698	A-3	REGULAR BROADCASTS
	UPON RECEIPT AND ON ODD HOUR INTERVALS	2698	A-3	EMERGENCY BROADCASTS
SEATTLE, WASH. (NMW)	0430 AND 1630	425	A-1	REGULAR BROADCASTS
	0500 AND 1700	2698	A-3	DO.
	UPON RECEIPT AND ON EVEN HOUR INTERVALS	425	A-1	EMERGENCY BROADCASTS
	DO.	2698	A-3	DO.
KETCHIKAN, ALASKA (NMJ)	0530 AND 1730	410	A-1	REGULAR BROADCASTS
	0530 AND 1730	2698	A-3	DO.
	UPON RECEIPT AND ON EVEN HOUR INTERVALS	410	A-1	EMERGENCY BROADCASTS
	DO.	2698	A-3	DO.
HONOLULU, T.H. (NMO)	0930 AND 2130	2698	A-3	REGULAR BROADCASTS
	UPON RECEIPT AND ON LOCAL ODD HOUR INTERVALS	2698	A-3	EMERGENCY BROADCASTS
	DO.	425	A-1	DO.

Inclosure B

Bell System Coast Harbor Stations
Broadcasting Marine Information

Station	Call letters	Frequency (kc.)	Present G.C.T. Schedule
Boston, Mass.	(WOU)	2506	0420-1620
New York, N.Y.	(WOX)	2522	0350-1550
Wilmington, Del.	(WEH)	2558	0430-1630
Norfolk, Va.	(WGB)	2538	0400-1600
Charleston, S.C.	(WJO)	2566	0400-1600
Miami, Fla.	(WDR)	2514	0400-1600
Tampa, Fla.	(WFA)	2550	0400-1600
New Orleans, La.	(WAK)	2598	0400-1600
Galveston, Tex.	(KQP)	2530	0100-1830
San Pedro, Calif.	(KOU)	2566	0400-1600
San Francisco,Calif.	(KLH)	2506	0430-1630
Eureka, Calif.	(KOE)	2506	0500-1700
Portland, Oreg.	(KQX)	2598	0210-1940
Seattle, Wash.	(KOW)	2522	0200-1930
Astoria, Oreg.	(KFX)	2598	0200-1930

Inclosure C

Stations Broadcasting HYDROLANTS and HYDROPACS

Atlantic Stations

Time (Greenwich civil)	Station	Call Sign.	Frequency in kilocycles. Type of emission A1 except as noted
0330	San Juan, P.R.	NMR	127
0400	Boston, Mass.	NMF	425
0400	New York, N.Y.	NMY2	474 (A2)
0400	Norfolk, Va.	NMN	410
0400	Miami, Fla.	NMA	482
0418	New Orleans, La.	NMG	448 (A2)
0430	Washington, D.C.	NSS	122, 4390 9425, 12630
0430	Balboa, C.Z.	NBA	5005, 11080
1030	Balboa, C.Z.	NBA	5005, 11080
1530	San Juan, P.R.	NMR	127
1600	Boston, Mass.	NMF	425
1600	New York, N.Y.	NMY2	474 (A2)
1600	Norfolk, Va.	NMN	410
1600	Miami, Fla.	NMA	482
1600	Balboa, C.Z.	NBA	5005, 11080
1618	New Orleans, La.	NMG	448 (A2)
1630	Washington, D.C.	NSS	122, 4390 9425, 12630
2100	Balboa, C.Z.	NBA	5005, 11080

Pacific Stations

0000	San Francisco, Calif.	NPG	115, 9255 12540
0000	Oahu (Honolulu) T.H.	NPM	16.68, 9050 13575 17370
0400	Long Beach, Calif.	NMQ	425
0400	San Francisco, Calif.	NMC2	418 (A2)
0400	Oahu (Honolulu) T.H.	NPM	16.68, 9050, 13575 17370

Pacific Stations (cont)

Time (Greenwich civil)	Station	Call Sign	Frequency in kilocycles. Type of emission A1 except as noted
0430	Seattle, Wash.	NMW	425
0430	San Francisco,Calif.	NPG	115, 4390 9255, 12540
0430	Guam, Marianas	NPN	155, 4265, 8530, 12795 17060
0530	Ketchikan, T.A.	NMJ	410
0800	Oahu(Honolulu) T.H.	NPM	16.68 4525, 9050 13575
1300	Guam, Marianas	NPN	155, 4265, 8530, 12795 17060
1600	Long Beach, Calif.	NMQ	425
1600	San Francisco,Calif.	NMC2	418 (A2)
1630	Seattle, Wash.	NMW	425
1700	San Francisco,Calif.	NPG	115, 4390 9255, 12540
1730	Ketchikan, T.A.	NMJ	410
2000	Oahu(Honolulu) T.H.	NPM	16.68, 9050 13575
2200	San Francisco,Calif.	NPG	115, 9255 12540
2300	Guan, Marianas	NPN	155, 4265, 8530, 12795 17060

Inclosure D

Stations Broadcasting Ice Information

Time	Station	Call Sign	Frequency in kilocycles. Type of emission A1 except as noted
0118 and 1318	Argentia, Newfoundland	NWP	480 (A-2), 8100
0400 and 1600	Boston, Mass	NMF	425
0400 and 1600	New York, N.Y.	NMY 2	474 (A-2)
0400 and 1600	Norfolk, Va.	NMN	410
0430 and 1630	Washington, D.C.	NSS	122, 4390, 9425, 12630

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN. · · · APRIL 28-MAY 9, 1947

OCEAN STATION VESSEL MARINE SERVICES

- By -

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ABSTRACT

This paper presents a brief discussion of the functions of Ocean Weather Stations together with an historical resume of the program and the need for the ocean weather stations in the postwar era.

The paper concludes with a nontechnical discussion of the services rendered by the ocean weather stations and their use to the maritime world.

OCEAN STATION VESSEL MARINE SERVICES

Introduction

1. There has been considerable discussion during this meeting regarding radio aids to Marine Navigation pointing directly to certain systems and methods for accomplishing the specific function of position fixing with some mention of anti-collision devices. Actually Marine Navigation includes a much broader field than that of position fixing alone. In addition, radio aids to Marine Navigation includes such things as distress and alerting communications, Weather Broadcasts, Medical Aid Communications, Safety and Warning Broadcasts, communications regarding routing of vessels and in some cases direct radio communications between vessels on the high seas.

2. A vessel on the high seas is at the mercy of weather, sea and sometimes ice and other floating obstructions. Further, the vessel's safety depends on the continued functioning of rotating machinery. I mention these things because we are likely to neglect this aspect of the problem when actually, in spite of all of our technical accomplishments, icebergs do exist and ships run into them, storms regularly occur and ships are damaged by them. Likewise, machinery ceases to function and we have a helpless vessel at sea. Anyone who will take the time to look over our Weekly Report of operations is likely to be taken aback by the large number of such cases that occur practically every day.

3. Fortunately for Marine interests, the requirements of ocean air transport have forced the issue for a proper ocean weather reporting system, and hand in hand with this system has come a windfall for the Marine shipping industry in the form of a proper rescue vessel dispersion on the high seas, these vessels being completely equipped with modern telecommunication facilities. This places in the hands of those concerned with safety of life and property at sea the most potential tool for distress prevention and relief that has ever existed.

4. In the most restricted sense an ocean weather station is merely a floating weather observation post. The station is equipped and manned as are the hundreds of other Weather Bureau Stations throughout the world. The purpose of all these stations is to observe, periodically, the various meterological elements, surface and upper air, and transmit this information to a central

Weather Bureau office for distribution, evaluation, and use. In this manner the ocean station vessel is providing a platform, in a fixed location in the ocean, from which weather observations can be made.

History

5. I am sure that all the maritime world is familiar with the prewar organizations for obtaining weather data from the ocean areas. If you remember, all vessels were requested to make standard reports at six-hour intervals whenever they were able to communicate with a shore radio station, and especially selected ships were designated by the Weather Bureau to make more detailed reports along certain routes. This program is now being reestablished by the Weather Bureau for the postwar era.

6. With the onset of World War II, surface weather reports which had normally been made by transatlantic shipping were discontinued because of the radio silence imposed on belligerent shipping and also because of the provisions of the Neutrality Act which prevented United States ships from engaging in European trade. The result was that practically no weather reports were received from the North Atlantic Ocean area. There was thus a manifest need for strategically placed ships which could provide the necessary meteorological data.

7. Therefore, in January, 1940, at the request of the Secretary of Agriculture (in whose Department the United States Weather Bureau then was), the President ordered Coast Guard cutters performing neutrality patrol off the Grand Banks of Newfoundland withdrawn from that patrol and reassigned by the Coast Guard to ocean weather stations in the Atlantic. Two of these stations were established early in 1940 between Bermuda and the Azores, with the Coast Guard providing the ships and communications facilities and the Weather Bureau providing the meteorological personnel and equipment. The total number of stations was gradually inincreased to eight in 1944 because of further demands for more complete meteorological data. The system eventually expanded to a maximum of 22 stations, seven of which were operated by the United Kingdom and 13 by the United States. For a short period two additional stations were manned by Brazilian vessels working with the U.S. Navy and based at Recife, Brazil.

8. Early in 1946, as demobilization of the armed forces approached completion, the strictly military needs for ocean weather stations lessened considerably, and the number of stations operated was reduced to four. However, the fundamental need for

the information supplied by these vessels still remained. The first steps to establish ocean weather stations on a permanent peacetime basis were taken at the North Atlantic Route Conference of PICAO in Dublin, Ireland, in March, 1946, when it was recommended that 13 ocean stations be established at specified locations in the North Atlantic Area. This recommendation of the Dublin Conference was approved by PICAO at Montreal, and a conference of the North Atlantic States to implement this plan was called in London in September, 1946. At this Ocean Weather Observation Station Conference, the following governments agreed to participate in financing and operating the thirteen recommended stations: Belgium, Canada, France, Ireland, the Netherlands, Norway, Sweden, the United Kingdom, and the United States. The agreement calls for the United States to operate seven of the thirteen stations and one additional station jointly with Canada. This agreement is an example of international cooperation to promote safety, regularity, and economy in intercontinental commerce. It provides a pattern for such cooperation by which nations could participate in furnishing other vitally needed facilities, like long range aids to navigation, in accordance with their use of such facilities. These facilities of general use need never come out of one nation's pocket.

Functions and Services

9. As previously stated, the primary function of the ocean station vessels is to observe and transmit weather information. Briefly, the observations consist of routine surface observations and obtaining the temperature, humidity and pressure in upper levels by radiosonde observations, also determining the force and direction of upper level winds by tracking with radar a free balloon carrying a radar target or reflector.

10. It is understandable that the ocean weather stations are located primarily to fulfill meteorological needs. In practice, this requires that the vessels be placed some six to seven hundred miles apart. Such arrangement, fortunately, establishes an almost perfect listening net for distress traffic on the international marine distress frequency of 500 kilocycles. Logical, then, is their additional function as search and rescue units. Ocean weather station vessels also provide navigational data to aircraft and ships, make oceanographical and other scientific observations, and perform such other functions as may be prescribed.

11. Specifically the services performed by the ocean weather station vessels which are useful to maritime interests can be listed briefly as follows: Improved weather forecasts; use of radiobeacon signal for both position fixing, and homing; radio

relay service (ships business and weather reports); medical advice and assistance; improved distress watch on 500 kcs plus additional distress watch on 8280 kcs; radar weather detection; ice information and advice as to other ships in the vicinity in case of distress. All or most of these services, useful to surface vessels, are part of the tradition of the sea and expected from a Coast Guard vessel wherever found.

12. The particular ability of the ocean station vessel to be of assistance is both direct and indirect in character. One of the direct uses of the ocean station is its ability to provide vessels in the general area with weather and sea information. If there is sufficient demand for such service, certain of the weather stations could have on board special personnel qualified to construct weather maps and to advise, upon request, as to the location and intensity of storm centers and the best courses for ships in individual cases to avoid winds and seas of destructive violence.

13. The indirect uses to the maritime world are much more far-reaching and offer, therefore, more ultimate benefit to the ship operators. We should attempt to learn from the experience of the war, lessons to be applied in peacetime operation. I refer in this instance to the wartime sailing conference, held in the Port Director's Office prior to the departure of each convoy, at which many of you will remember there was discussed, among other things, the weather situation along the convoy's route and how it would affect the convoy. Of course, during wartime our concern was not so much with fuel consumption or time en route, or economy, as it was with the submarine menace, air coverage, changes of escort, and other things. But even as weather and rescue played a vital part in these wartime considerations, it does, as you well know, play a vital part in your present-day operations. To have a major liner materially damaged at sea, delayed a day or more en route, to have passengers or crew injured through the violence of a North Atlantic storm, is very poor business no matter how you view it. I think you will agree that both the passenger agent and the advertising man would take a dim view indeed of such a situation. We cannot hold up sailings or disrupt schedules, or wish the storms away, but we can know a great deal about storms and sea conditions and take intelligent steps, not only to avoid the violence of the storm, but to use its location and movement to our advantage. The presence of a network of ocean station vessels reporting to central information offices provides so much additional information concerning sea and weather conditions that it is not only possible but practicable to inform the ocean steamship operators day by day of sea conditions and to give pertinent advice on their sailings in order to avoid the destructive violence

of wind and sea. If a liner can by a slight deviation from the usually traveled route pass a storm to the northward instead of the southward and so obtain following winds instead of head winds, no time will be lost, no damage will be sustained, and the ship will arrive on schedule.

Conclusion

14. It can readily be seen, therefore, that the ocean station vessels fit smoothly into the comprehensive problem of marine navigation and constitute an important part of an integrated system to promote increased safety of life and property at sea.

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ELECTRONIC AIDS FOR THE CONTROL OF HYDROGRAPHIC SURVEYS

- By -

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ABSTRACT

This paper discusses the use of electronic equipment for the control of hydrographic surveys. It describes one particular system in some detail, although it does not go into the theoretical considerations in any way. The actual uses of the equipment in one extensive survey are described.

ELECTRONIC AIDS FOR THE CONTROL OF HYDROGRAPHIC SURVEYS

1. During the past five or six years there were many electronic devices made primarily for the determination of the distance between two tangible objects. The general purpose was, of course, to locate one object with respect to another, as, for example, the shore with respect to a moving ship, or one ship with respect to another, and so on. These could all be classed as position finding equipments if they were used in connection with some stationary objects of known position. In general these all used the principle of uniform velocity of the electromagnetic wave through free space, and that it would reflect from an object and return to the original source, and thus make it possible to determine the distance. The accuracy of this distance measurement depended upon the quality of the measuring device as well as the reflecting power, or aspect, of the target. To obtain a more definite target from which echoes could be obtained, the racon was developed. Then, with the use of two or more of these racons the position of the craft could be determined with an accuracy which was excellent for navigational purposes. This racon was a transponder, which, on being challenged by a ship's radar, would reply, pulse for pulse. The indicating "scope" in the radar would then present the information from which both distance and azimuth to the "target" could be obtained. This racon was about as simple a piece of equipment as could possibly be made and still function with a moderate degree of accuracy. It is about some such system as this that this short discussion will be on.

2. Two of this type of navigating systems which were developed during the last few years are LORAN and SHORAN. These two systems are somewhat alike, but in the actual application of these principles they are quite different. They are alike in that they both have a master station and two slave stations; but in Loran all three of these stations are ashore and the moving craft is equipped merely with a measuring device which will tell only the difference in time of arrival of the slave pulses with respect to the master's signals, since it can in no way see when the signals were started out from the ground stations. This time difference between the arrival of the signal from the master station and either of the two slave stations will then be plottable on a chart as a hyperbolic line (or lines) of position, and the intersection of two of these lines will be the position of the craft. The rapid divergence of these lines of position as the craft goes away from the base line, then will cause increasing positional errors in distance, but which remain approximately constant relative to the distance.

3. Now, in Shoran, the master station is on the moving craft,

and this includes the time measuring device. Therefore, the distance to the master station is always Zero, and the other distances measured must be the actual distances to the two slave stations. The Shoran System then becomes a "two-circle" system, and a position is indicated by the intersection of two circular arcs the centers of which are the two ground stations.

4. Shoran is the only Radar system which was specifically designed as a high precision position finding equipment for a very special purpose during the war. It has been adopted by the U. S. Coast and Geodetic Survey as a control for hydrographic surveys in areas beyond the practical use of visual control. With two ground stations established at accurately determined positions ashore, the equipment on board the surveying vessel will supply the hydrographer with instaneous information as to his position by indicating the distances from the two ground stations.

5. It is not necessary to go into any great detail as to the functioning of the various components of the system to tell how it works. As already pointed out, the ship equipment is the master, and the two ground stations are the slaves. The ship equipment transmits signal pulses or challenges, to each of the two ground stations in turn, where they are immediately retransmitted back along the same path over which they came. Novel circuits in the ship equipment automatically measure the time elapsing between the challenge and the reply and convert these into distances in statute miles between ship and ground station. These two distances then are the required data for the two-circle fix. This is the particular fact which makes Shoran the high precision position finding equipment it is. Whatever error may be found to exist in one measurement can be applied to all distances to correct them. The errors may not be exactly the same numerically for all distances, but they are of the same order; and the relative error decreases materially as the distances increase.

6. Shoran radio frequencies automatically limit the useful range of the system to a little more than the line-of-sight distances. This is not exactly true for the short distances usually obtaining in hydrographic surveys. Actual practice has indicated that the useful range is about 1.6 times as great as the optical distance, so with ground stations at an elevation of about 250 feet and the ship's antenna about 80 feet, the line-of-sight distance is about 33 statute miles, while the actual effective range of the equipment is nearly 50 miles.

7. The ship equipment transmitter challenges on two frequencies, one about 230 and the other about 250 megacycles per second. Its receiver is tuned to a frequency of about 310. The transmitting circuits are designed to challenge each ground station alternately

at a rate of about ten times per second, each on its own frequency; at the same time, these circuits permit the replies from the particular ground station to be presented in the proper position in the indicating tube for the measurement of the distances. Each ground station receiver is tuned to one of the two frequencies mentioned, 230 or 250 mcps. The challenge is received, amplified, and retransmitted on 310 to the ship where it is properly selected as already noted. The system is designed to permit the operation of a relatively large number of ship equipments without mutual interference, but in hydrographic surveys to date, only two surveying units have used the same pair of ground stations at the same time.

8. The presentation of the data in the indicator is by circular sweep on a three-inch cathode ray tube. This sweep is about 2 inches in diameter making the circumference nearly 6 inches. A reference pip, or marker, appears near the top of the tube, on the outside of the circle. The two distance pips appear, one on the outside and the other inside, in positions relative to their distances from the ground stations if the measuring device reads "zero These distance pips are movable by the vernier system, and can be brought into alignment with the reference pip. When this is done, the vernier reading is the distance in statute miles to the ground station for which it is the control.

9. The distance measurements are made through a goniometer system which comprises a Calibrated Phase Advance Network for each ground station, and the verniers to make the actual measurements. This is called the Calibrated Phase Advance Network because of the way it is used. The reference pip is stationary—and represents the transmitted signal and the reply, were the distance "zero." Now, as the ship departs from the ground station, the challenge pip would still appear at the marker and the distance would seem to travel around the sweep in proportion as the distance varied. When the distance pip is brought into coincidence with the marker, it has been necessary to advance the challenge in the same proportion ahead of the marker. Thus it is seen that the challenge then is made prior to the marker in a time exactly equivalent to the distance between the ship and the ground station.

10. It will be assumed for the purposes of this discussion that the velocity of electromagnetic waves in free space is 186,000 miles per second, although the equipment is actually calibrated for a velocity of 186,218 miles. With a challenge rate of 930 pulses per second, it can be seen that the rate of challenge will correspond to a round trip travel time of 100 statute miles, so that the system merely begins repeating after passing the 100-miles distance. It is therefore necessary to know one's position to within 100 miles to obtain an accurate fix. The circular sweep has three speeds, corresponding to a travel time of 100, 10, and 1 mile per sweep, or

with apparent sweep speeds of 930, 9300, and 93000 times per second. It can be easily appreciated that, when the sweep length is nearly 6 inches, it is relatively easy to divide this length into very small divisions, so that hundredths, or even thousandths of a statute mile may be read. This division is the function of the verniers, which read directly to hundredths, and, by estimation, to thousandths of a mile (which is approximately five feet). Certain other refinements have been necessary to make this equipment as accurate a distance measuring device as possible. It is well known that there are certain delays occasioned in the passage of radio signals thru the circuit elements in receivers and transmitter, transmission lines, and so on. When very small intervals of time are to be measured, these delays take on a relatively great importance. They are considered very carefully in the design of Shoran. The method employed is to increase the actual lag to some definite value considerably greater, for these lags cannot be reduced. Therefore the ground stations are designed to include a Variable Delay, and a Calibrated Fixed Delay by means of which the actual station delay is standardized at a relatively large value. Similarly, the delay in the ship equipment is determined individually, for each installation is a problem in its own right. The two lags are then added together, and this sum subtracted from Zero on the verniers. In the calibration of the ship equipment, the marker pip is then adjusted to be in coincidence with the transmitted signal from the ship, when the verniers read somewhat less than zero—say 99.845, for example, in which case then the total instrumental error (lag) has been determined to be 0.155 statute mile.

11. The Shoran indicator equipment is time-controlled by a 93.109 kcs crystal; this frequency then corresponds to a one-mile loop distance per cycle. Since these equipments were designed for use in aircraft, certain control elements were omitted in the ship equipment, and made a part of the ground equipment, instead. The crystals in the ground stations are high precision thermally controlled units; and from certain signals transmitted to the ship from these stations, the ship crystal is pulled into exact synchronism with them.

12. The U. S. Coast and Geodetic Survey was the first organization to use Shoran for the control of hydrographic surveys. This was in the late summer of 1945 when some experimental work was done in the western Aleutians by the Ship EXPLORER. In this experimental work, the most important study was made of the possible position error when using this system. Of course it was studied with reference to the effects on a hydrographic survey where very small position errors are tolerated, but which would not be acceptable in triangulation even of the second order. The various errors in the equipment might, if all accumulative at the same time, be of the order of 25 feet in any one distance. But it can also be shown

that the error in position obtained by three-point fix on shore signals may also be out approximately the same amount, since it is generally not practicable to read angles closer than the nearest minute. An error of one minute on angles of 30 degrees, and at a distance of ten miles from the signals will cause a displacement of position of about 12 feet, but at 20 miles nearly 50 feet, and increases proportionally. The Shoran error remains practically constant over the range limits. Other tests were made to determine the actual total system delays for any combination of ship and ground equipments. The data obtained from these tests and from other work done in the spring of 1946 proved that this system was excellent for the control of hydrographic surveys. Large scale operations were planned for the summer of 1946, in which the Coast and Geodetic Survey Ships EXPLORER and SURVEYOR were to take part. These surveys were to be made in the waters surrounding the Near Islands—the westernmost group of the Aleutian Island Chain. This is an area of plentiful fogs and low visibility in the summer, with its share of bad weather, all of which make it difficult to carry visual control very far off shore; but at the same time make it ideal (if that were possible) for control by Shoran.

13. As in making any new survey, the "lay of the land" must be studied beforehand from the best available charts and maps, then studied by actual reconnaissance on the ground, so as to take the greatest advantage of any special topographic features. In using Shoran there are several points to consider when making plans for ground station installations. These are accessibility, elevation, and station separation. A station should be accessible primarily for getting the materials and equipment ashore from the ship (usually) and should be so chosen that it is accessible in most any kind of weather for servicing when required. Elevation is important, but the cost and labor of placing a station at great elevation should be carefully weighed against the relatively small gain in effective distances, and also the fact that long distances from one station at high elevation cannot be matched by distances from another at a much lower elevation. The area covered by a pair of ground stations is materially affected by the length of the base between the two stations. It appears that the optimum distance between two ground stations is about eight-tenths the range expected from the lower of the two ground stations. Thus, if the expected range of the station at the lower elevation is 50 miles, the separation of the two stations should be about 40 miles plus, and then the area covered will be approximately square, with an extent of about 2500 square miles.

14. The distance which might be expected to obtain from a ground station is given roughly by the formula

$D = 2(\sqrt{h} + \sqrt{k})$, where
D = the distance in statute miles
h = the height in feet of the ground station antenna
k = the height in feet of the ship's antenna.

15. As soon as the sites for the ground stations have been definitely selected, the positions for the various antenna systems should be located by triangulation. At the same time that the stations are being built, the projection for the work, or, as it is usually called, "the boat sheet", should be prepared. This will ordinarily be on a scale such that the entire area controlled by a pair of stations can be gotten on the sheet, with both ground stations plotted on this sheet. In some cases it might be desirable to make the sheet considerably larger than usually permitted, in order to plot both control stations, for it is much easier to draw in the distance circles accurately with a beam compass from an actual center than it is to compute the positions for the circles and then draw them in with a long spline. Excess paper can easily be cut off. The standard maximum size sheet is 42" x 72", but it has been found expedient to make the sheet as long as 100 inches to facilitate drawing in the control. The arcs of equal distances are usually drawn in in colored ink, one color for each ground station, to prevent confusion. The interval between arcs varies from two statute miles on a 1:40,000 scale to 10 miles on scales of 1:160,000 and 1:200,000.

16. The actual plotting is done by means of a special device called an "Odessey Protractor." This is made of plastic, to the same scale as the survey sheet. A series of concentric circles are drawn or scribed, the circle interval being either 0.1 or 0.2 statute mile, depending upon the scale. The radius of the protractor is equal to the interval between distance circles on the sheet. Circles are identified by small numerals placed on two diameters perpendicular to each other. By means of this protractor, the interval between two adjacent circles may be subdivided very quickly directly into tenths, and by estimation into hundredths of a statute mile, and odd mile distances obtained by adding the small excess over a distance circle to that circle. Two distances may be plotted in a very short time with a little experience, and it is possible to plot a fix within ten seconds after the data are available.

17. The general plan for the field work for the 1946 season called for the surveys of the waters surrounding the Near Islands which include Attu and Agattu Islands and the Semichi Group of Alaid, Nizki, and Shemya. The areas to seaward were to be surveyed to a depth of at least 1000 fathoms, or to the limit of adequate Shoran control. The requirements were easily met, and in general control was adequate to carry sounding out to well over 2000 fathoms on the north and 4000 on the southwest.

18. In making the surveys of the area around the Near Islands, the hydrographer was confronted with rather serious limitation in sites suitable for ground stations. Instructions called for the surveys of the shoal areas to the westward of Attu to the 170th

meridian East, which meant carrying control about 110 to 115 miles from Cape Wrangell, which is the westernmost point of land. This cape is of sufficient elevation to make it possible to obtain 110 miles, but single-arc control is poor at such distances. The chart of this area shows a shoal of about 24 fathoms some 55 miles offshore almost west of the Cape; and it was possible to anchor a floating ground station there to control the entire survey in conjunction with one on the Cape; at least the control would be adequate over all but the most western limits. The ground station was established on Cape Wrangell, at an elevation of about 1800 feet in approximately a week's work, requiring a considerable amount of labor for all equipments and material and supplies had to be back-packed up the mountain. This station was called DAR. Immediately the station was completed and operating, the Ship SURVEYOR made a reconnaissance run to the westward to locate this shoal. The least depth found on this run was 18 fathoms at about 65 miles from DAR, with an approximate azimuth of 280°.

19. As weather conditions were still poor, a second station was established on eastern Attu Island, on a point of land to the westward of Chichagof Harbor. The elevation was about 250 feet. This station was called CHICO. Using these two stations, DAR and CHICO, the area to the north, and northwestward of Attu was surveyed to some distance beyond the present chart limits, and completed by the end of July.

20. Preparations for the survey of the western areas had been continued during this time. A large buoy with a marker was planted near this 18-fathom shoal to serve as a permanent reference point during the surveys. It was planned to moor the Ship SURVEYOR to the mooring buoy, thus make it possible for her to maintain position with reference to the marker buoy. But this didn't work out too well, and it was necessary for the ship to use her own ground tackle.

21. A ship equipment and a ground station were installed in the Ship SURVEYOR so that she could act either as a survey ship or a ground station. The same antenna array was used for both installations, and change-over could be effected in about 30 minutes.

22. It was decided that, once this survey was begun, to stay with it until it was completed. The instructions for the survey of this area called for development to at least 1000 fathoms on the north and south and to the 170th Meridian East on the west. The Ship SURVEYOR took station near the reference buoy and made a satisfactory determination of the distance buoy to DAR, then changed operation to ground station. Distances were successfully measured between the Ship EXPLORER and the stations DAR and CHICO and the Ship SURVEYOR. Distances measured by and to the Ship SURVEYOR were adjusted so that they represented the distances to the reference buoy.

Since the geographic positions of DAR and CHICO were known, it was a simple matter to compute the position of this buoy. It is probable that the position of the buoy was within 100 feet of the true position. The survey of this area which was about 5500 square miles in extent was completed in about 160 hours actual time. The survey was done in three periods, 30, 75, and 55 hours, these being separated by a severe storm lasting several days in the first instance and by equipment failure in the second. The latter delay was only for about 8 hours.

23. In these two surveys, the maximum distances obtained were 113 miles from DAR, 74 from CHICO and 48 from the SURVEYOR. The average useful maximums were about 100 from DAR, 55 from CHICO and 35 from the SURVEYOR, all of which agree quite well with the distances computed by the formula already mentioned.

24. A third ground station was established on the western end of Aggatu Island at an elevation of 1000 feet. The construction of this station was materially expedited by the use of a weasel which handled the transportation of all material and equipment. This station was called IMP. It was used primarily in conjunction with DAR for the control of the areas to the west and south of Agattu Island, where good control was carried offshore to depths of about 4000 fathoms. In this part of the survey, distances as great as 95 miles were obtained from IMP, but the average reliable maximum was nearer 85 miles.

25. A fourth station was established on Shemya Island at an elevation of 300 feet, at a primary triangulation station named STAR. This station was used together with CHICO to survey the area northward of and between Attu Island and the Semichi Group. It was necessary to use station IMP for the part of this survey which extended south of the base line, for CHICO was cut out by the high land on the eastern tip of Attu Island. Distances as great as 50 miles were obtained from STAR, but this was not necessarily the maximum.

26. To complete the survey of this area, it will be necessary to reestablish station STAR on Shemya Island, and CHICO on Attu Island, and build another on Agattu Island, probably on the southeastern point on Cape SABAK. These stations should easily carry good control as far east as the 175° 30' East. A station on Buldir Island, and a floating station on Tahoma Reefs to the south will afford excellent control in the area south of Buldir Island. Any elevation up to about 2500 feet may be had on Buldir Island, but the establishment of a station there will mean a great deal of labor and time; but since it would be a key station, the effort and time expended would be well compensated for in the results

obtained. It is possible to use a weasel for hauling material and equipment most of the way up the mountain. It might be more practical to establish a temporary station at a lower elevation than the top, for controlling the western areas, then shift to another point when that part has been completed. The probable distance to be obtained from an elevation of 2000 feet is 110 miles, only a little less than that from 2500 feet, which is 120 miles. That last 500 feet will be very difficult.

27. There are two great advantages gained with the use of Shoran for the control of hydrographic surveys. These are the great accuracy of the control and the fact that weather, in so far as visibility is concerned has no effects on the operations under way. As with all types of radar equipment, fog and haze have little effect, and with the type of presentation, rain, snow, and static effects are almost negligible. Control is excellent until the maximum range has been reached—a point which is significant, for the signals disappear almost at once.

28. Actual delays on account of station failures were very small, a total time of about 16 hours, which would have been spent in surveys, were lost in this way. All the failures occurred at ground stations; none in the ship equipments. One indicator equipment has operated for a period of nearly 1000 hours without any adjustment other than the routine. Most of the equipments were used in excess of 600 hours, which speaks very well of their ruggedness. All equipments have had a thorough overhaul during the past several months in preparation for extended operations this summer.

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INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN · · · APRIL 28-MAY 9, 1947

THE PRODUCTION OF NAUTICAL CHARTS FOR RADAR AND LORAN

- By -

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ABSTRACT

This paper discusses various solutions of modifying the conventional nautical charts to make them useful for navigating with radar and Loran without impairing their usefulness to the navigator whose ship is not equipped with these electronic aids.

THE PRODUCTION OF NAUTICAL CHARTS FOR RADAR AND LORAN

1. Several new aids have been made available to the mariner by the application of electronics to navigation. As in the case of visual aids, the value of these new aids depends largely upon the manner in which they are charted.

2. As buoys, beacons, or lighthouses can be identified by a glance at the chart, and a position determined readily, so should the modern mariner be able to identify and use these new aids to navigation with equal facility. It is the cartographer's province to design new charts or to modify conventional charts to accomplish this purpose. Of course, the ideal solution would be to adapt the present charts to these new tools, without in any way impairing their usefulness to the non-electronic navigator. By so doing, ships equipped with radar, Loran, and the like would not be required to carry a second, or possibly a third, set of charts.

3. First, I should like to discuss the adapting of the nautical chart for use in navigating by radar. It is well known that radar radiation approximates, at least in theory, a line of sight. Consequently, all objects of sufficient height and within range of the equipment should be potential targets for position determination. The charting of such objects along the shore, whether they be responder beacons, reflectors, or so-called radar conspicuous objects, presents no problem, because their positions can be denoted by symbols; in fact, special symbols for such objects are to be considered by the International Hydrographic Bureau at this year's meeting in Monaco.

4. Aside from the charting of these radar aids, we are presently concerned with the cartographic treatment of the land relief on the conventional chart in a manner that will best utilize topographic features for radar navigation.

5. When the coastal features are within range of the radar equipment, an accurate delineation of the shore line will in most cases be sufficient. This is particularly true in areas of rather steep shores where the features will appear on the screen very much as they are charted. The addition of contours, however, would often allow better identification as in the case where occasional valleys run back from the coast. These lowlands will often appear on the scope as deep indentations in the shore line and a close contour interval, perhaps as close as 50 feet up to 200 feet in some instances, may be desirable to emphasize features of this sort.

6. Along the low-lying coast the addition of contours may be helpful to the navigator, but in many cases a position from dead reckoning or other aids will be a necessary adjunct to accurate interpretation of the scope.

7. When the shore line and adjacent bluffs are below the radar horizon, the navigator must make use of interior topography, and it is the delineation of this topography which presents the greatest problem. Many suggestions have been received as to how this should be accomplished, including recommendations that only prominent peaks or hills be shown by hachures and that seaward faces only of potential targets be contoured. Both of these suggestions have merit in that the chart would be kept cartographically simple and hence economic in production. Such a chart, based upon a proper amount of field investigation, undoubtedly would be satisfactory for average conditions of radar reception. However, the picture would be far from complete and under abnormal conditions of reception could be confusing or useless to the mariner. I believe that this interior topography should be shown completely.

8. Generally speaking, contours are obtained from large-scale topographic maps which have a smaller contour interval than is necessary or desirable for a relatively small-scale chart. The contours on the topographic maps were originally drawn with an eye to topographic expression; but for the purpose of the radar chart, the contour interval must be increased and the contours somewhat generalized. The illusion of relief often can be enhanced by a very slight shift in the position of the contours, particularly in depicting shoulders and saddles.

9. I believe that contours alone are not sufficient to picture relief for the mariner, regardless of the interval used or the skill with which they are drawn. The Coast and Geodetic Survey has produced several experimental charts with the contours and gradient tints in brown to emphasize the relief. On these charts the relief stands out with clarity and the relative heights and masses of hills and mountains, the natural radar targets, can be determined quickly and easily.

10. I must emphasize that gradient tints, if proved successful for the purpose intended, will be confined to coast charts of intermediate scale. Large-scale charts need no such treatment; the shore line, together with artificial and natural radar beacons and objects which will be charted by conventional symbols, will suffice.

11. Considerable study has been given another tint method of charting hills and mountains which have been proven by experience to return radar signals in varying degrees of strength. Such an object returning a strong signal would, for example, be tinted a deep brown, another returning a moderate signal, a lighter shade of brown, and so on. A hill or mountain returning signals of different values, depending upon the direction it is approached, would be represented by gradient tints in vertical bands.

12. Adapting the nautical chart for the use of Loran as a long range aid to navigation presents more difficulties than radar. The hyperbolas representing the Loran lines of position, their designation as to station pairs by color and micro-second value by numeration, appear, of course, on the water portion of the chart, whereas any features added to the chart for the use of radar are charted on the land area. Overprinting the conventional chart with the Loran curves results in such a congestion of soundings, depth curves, compass roses, and Loran data that the usefulness of the chart for navigation would be seriously impaired.

13. There are special Loran charts for all areas of the world served by the Loran system. These charts are entirely adequate for position determination by Loran. However, in some localities or under certain conditions, a Loran position may be strengthened by using in conjunction with it an astronomical line of position, a radio bearing or a line of position obtained by echo soundings. The approaches to New York are an example of this--the Loran intersections are weak, but radio beacons are available for direction finding and the configuration of the ocean bottom is such that echo soundings are a valuable aid.

14. When the Loran is used either with or without one or more other aids to navigation, the navigator is forced to use both the special Loran chart and the nautical chart, transferring his Loran position or lines of position from the former to the latter in order to correlate them properly with his depth curves, radio bearings or sun sight. The mariner should not be burdened with such a procedure, and before doing so would probably prefer to plot his Loran curves directly on the nautical chart from available tables.

15. It follows, therefore, that for maximum usefulness of this aid while approaching the coast, the nautical and Loran charts must be combined in some manner. The Coast and Geodetic Survey has received numerous suggestions in regard to printing the Loran information: (1) to print it on the back of the standard chart for use over a light table; (2) to print it on a separate transparent overlay; and (3) to print it in a fluorescent ink which

would be invisible under ordinary light but which would glow under an infra-red light. These suggestions have been investigated and objections have been found in each of them. The light-table method offered the most promise, but it was found that regardless of how translucent the paper or how bright the lighting from below, there was difficulty in identifying the Loran lines. The overlay method, whereby the Loran data are printed on tracing paper or on a thin plastic to the scale of the chart, has the objection we are trying to eliminate--multiple charts. The fluorescent ink idea requires special printing as well as special equipment aboard ship.

16. The Coast and Geodetic Survey has produced an experimental chart with the Loran system printed in reverse on the back of the standard nautical chart and in register with the face of the chart. A position as determined by Loran is transferred to the face of the chart, with merely a prick point through the chart. The advantage of this method is a quick and positive transfer of position. The disadvantage is that Loran lines of position cannot be used with other aids as mentioned above unless transferred through the chart in a like manner, a relatively slow process.

17. The Coast Survey also has in the process of reproduction an experimental chart whereon the Loran curves will be overprinted on the standard chart. On this chart all detail of the conventional chart will be printed in gray instead of black. Thus the detail in the water areas will be subordinated to the Loran data, but will be available for use when required. Another experimental chart will show the basic information in black instead of a subdued color, but with all soundings deleted. The depth curves will be retained, and additional ones added for fathometer use. It is planned to print these Loran combined charts on the reverse side of the conventional charts.

18. I must emphasize the fact that the charts I have been discussing are experimental. The ultimate design will, in a large measure, result from the suggestions and criticisms of the mariner in using these experimental types.

19. Because Loran is an aid to offshore navigation, and other aids are available when entering or navigating harbors, the Coast and Geodetic Survey will, for the present at least, confine its coverage to the small-scale general charts of the coast.

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SOME EXAMPLES OF THE USE OF MARINE RADIOTELEPHONY FOR SAFETY PURPOSES AND AS AN AID TO NAVIGATION

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ABSTRACT

This paper describes the application of marine radiotelephony for safety and navigational purposes on the Great Lakes. Illustrations are given of navigational uses for radiotelephony. Operational studies of the application of VHF radiotelephony using frequency modulation as conducted on the Great Lakes are briefly described and the potential value of these frequencies for short range marine radiotelephony generally is set forth. The paper calls attention to the action of the Interim Executive Committee of the Radio Technical Commission for Maritime Services endorsing frequency modulation for use in the 30 to 300 megacycle band and to the position taken in the United States frequency service allocation proposal respecting the desirability for international standardization upon the frequency 156.81 megacycles for the exclusive use of the maritime mobile service for short range communication.

SOME EXAMPLES OF THE USE OF MARINE RADIOTELEPHONY FOR SAFETY PURPOSES AND AS AN AID TO NAVIGATION

1. The first practical application of "wireless" was to ship-to-ship and ship-to-shore communication. The first interational radio conferences were primarily concerned with standardization looking toward universality of communication in this field. The continuance of this universality in radiotelegraphy and its extension into certain phases of marine radiotelephony will be one of the subjects discussed at the forthcoming International Telecommunications Conference to be held in this country beginning 15 May 1947.

2. During the last 14 years there has been developed on the Great Lakes an international radiotelephone communication system of considerable magnitude and complexity. Some description of this system with examples of its use for safety and navigational purposes may be helpful in evaluating the future application of radiotelephony to marine needs elsewhere.

3. Some statistics on Great Lakes shipping were given by Mr. Jansky in his lecture on radar before this conference. Much more detailed information on this subject as well as on the navigating problem on the Great Lakes will be found in the Report On the Great Lakes Radar Operational Research Project, copies of which are available to those attending this conference.

4. The first use for radiotelephony on the Great Lakes was primarily to satisfy the need for communication between ships' officers and the home offices of the ship operating companies and for similar purposes. However, attention was soon directed to the value of ship-to-ship communication for safety and navigational purposes. The earliest important ship and shore radiotelephone installations on the Lakes were made in 1933 and 1934. By June, 1939, there were a total of 141 United States ships on the Great Lakes equipped for radiotelephony and by July, 1946, the number had reached 498. Canadian vessel owners on the Lakes were also active during this period of time and by 1946 had equipped 164 vessels.

5. There is operating on the Great Lakes a combined United States and Canadian fleet of 669 vessels of 500 gross tons and over of which 336 are bulk cargo freighters, the balance being car ferries, tankers, package freighters, passenger vessels, etc. Since most of the total of 662 Canadian and United States Great Lakes radiotelephone equipped vessels are in the category described above, it can be seen that the application of radiotelephony to Great Lakes shipping has almost reached the saturation point in so far as the number of mobile installations is concerned.

6. Prior to 1939 the frequency allocations to Great Lakes vessels and shore stations did not provide the universality of communication necessary for safety-distress and navigational use. This was corrected by the cooperative efforts of the Canadian and United States Governments and the Canadian and United States vessel owners' associations which resulted in the assignment to the Great Lakes of 2182 kilocycles for radiotelephony for both the Canadian and United States government and private ship and shore stations. An important step in the program designed to increase the value of radiotelephony for safety and distress communication was the equipping of a large number of United States Coast Guard life-saving and other stations for this frequency also. Today the Great Lakes radiotelephone system includes the following:

a. 662 Canadian and United States vessels
b. 85 United States Coast Guard shore stations
c. 7 Canadian coastal harbor shore stations
d. 7 United States privately operated coastal harbor stations

7. All ship and shore stations are equipped for radiotelephony on 2182 kilocycles and maintain an open loud-speaker watch on this frequency. Contact between ships and between ship and shore stations is made by voice calling on this frequency. While highly important communications such as those pertaining to distress take place on 2182 kilocycles, normal ship-to-ship communication is transferred to the second ship-to-ship frequency, 2738 kilocycles, after contact has been made.

8. The Canadian and United States commercial radiotelephone communications circuits, most of which permit interconnection with land wire telephone systems, use the same apparatus but other frequency assignments. It is not within the province of this paper to discuss the business and commercial systems in detail, but some comment is desirable. Briefly, in the United States, all ship and most of the shore stations are equipped for duplex operation with pairs of frequencies in the 2, 4, 6, and 8-megacycle bands. The use of these high frequency channels in general makes it possible to contact a vessel from shore at almost any location on the Great Lakes. On these commercial circuits, selective ringing is extensively used.

9. The Canadian commercial system is somewhat different from that in the United States in that frequencies above the 2-megacycle band are not so extensively used although some Canadian vessels are equipped with the higher frequencies in order that they may contact United States commercial coastal harbor stations. However, on the 2-megacycle frequency band there is complete universality in ship-to-shore communication between the vessels and shore stations of both nations.

The amount of business traffic handled by the commercial communicating systems is very great; and during the season of navigation, the frequencies assigned to this service are very extensively used.

10. As was described by Mr. Jansky in the paper on The Application of Radar to Lake, River and Passage Navigation, ship traffic throughout the Great Lakes and particularly along certain courses is very dense. Since universality was obtained by the assignment of 2182 kilocycles to the Great Lakes in 1939 and the equipping of all ship and shore stations for this frequency, there has been a steady growth in the use of radiotelephony for safety and navigational purposes. The following are a few illustrations.

11. Under unusually difficult ship traffic situations such as exist when visibility is poor, the movement of vessels approaching and entering the locks at Sault Ste. Marie is directed and controlled by radiotelephony. Ships meeting and passing in confined waters use radiotelephony to exchange passing instructions. Vessels use radiotelephony to notify Coast Guard stations concerning misplaced and inoperative aids to navigation, and other hazards. A vessel entering a lake and uncertain of weather conditions ahead for distances of 50, 100 or more miles (80, 160 or more kilometers) will telephone ahead to other vessels to secure up-to-the-minute information. Certain of the harbors on the Great Lakes have narrow entrances and somewhat tortuous approaching channels. It is standard practice for a vessel entering one of these harbors to call other vessels in the harbor to make certain that none is leaving and to determine the condition of traffic in the harbor. As an adjunct to radar navigation, the radiotelephone is already proving valuable for identification of targets and for exchange of information between radar-equipped vessels, as well as for warning ships not equipped with radar of potential danger. All of these uses for radiotelephony and many others similar in character provide preventative safety communication, the purpose of which is to keep navigation safe and to prevent ships from getting into trouble. This type of communication is not so spectacular, but it is just as imporant as the exchange of distress messages which occur after a vessel is in trouble.

12. Radiotelephony has performed outstanding service during periods of violent storms such as sometimes occur in the early spring and the late fall and occasionally in the intervening months. The record will show numerous instances in which ships have been called to the aid of a vessel in distress by radiotelephony, just as on the high seas similar service has been rendered by radiotelegraphy. However, on the Great Lakes the distances are such and the density of ship traffic

so great that radiotelephony is better adapted to distress communication. On the Lakes the ship navigating officers are licensed radiotelephone operators. When one ship goes to the assistance of another, communication affecting salvage operations takes place directly between the captains of the vessels concerned. This is an outstanding advantage of this type of communication.

13. There exists on the Great Lakes an extensive weather and storm warning broadcast service participated in by United States Coast Guard stations and by the coastal harbor stations of both the United States and Canada. In addition to regularly scheduled broadcasts of wind and weather bulletins, special storm warnings and other information of urgent importance are disseminated on short notice. The value of these broadcasts to Great Lakes shipping is very great.

14. The radiotelephone set aboard a Great Lakes vessel has become an exceedingly important instrument of navigation. The standard set aboard a United States vessel will have six channels, 2 for ship-to-ship and other navigational communication, and 4 for commercial communication. A continuous loud speaker watch is maintained on 2182 kilocycles at all times the ship is under way. Selective ringing is used on the commercial communications channels. Not only are handsets installed on the bridge and in the captain's quarters but in some instances a third installation is made directly adjacent to the captain's position before the front window in the pilot-house. This enables the navigating officer in charge of the ship to communicate with other vessels around him, with Coast Guard stations, and with commercial shore stations without leaving his post for an instant.

15. An analysis of safety and navigational communication on the Great Lakes places considerable emphasis on ship-to-ship and ship-to-Coast Guard station communication. While under certain circumstances this type of communication takes place over considerable distance, a large percentage of it is confined to distances less than 50 miles (80 kilometers). This has resulted in some consideration of the potentialities of VHF communication on much higher frequencies. If such frequencies were added to the present system, they would relieve some of the growing congestion due to the steady increase in navigational communication.

16. There has been some exploration of the potentialities of VHF communication on the Great Lakes making use of a number of single channel VHF frequency modulation sets operating on 37.58 megacycles. These were loaned to United States Great Lakes shipping owners for the purposes of

these studies by the United States Coast Guard. The results of these studies have not been completely analyzed; and Lake Carriers' Association, which sponsored the tests, has not arrived at any definite conclusions. In addition to the some 30 Great Lakes vessels and a smaller number of Canadian vessels equipped for 37.58 megacycles, the United States Coast Guard equipped 4 of its shore stations for this frequency. The companies operating some of the commercial coastal harbor stations in the United States did likewise.

17. A detailed record was kept of all communications carried on with the frequency modulation sets operating on 37.58 megacycles. A preliminary analysis of approximately 2,000 contacts showed a reliability for ship-to-ship communication of approximately 90 per cent for circuit distances up to 40 or 50 miles (64 or 80 kilometers). Beyond this, as would be expected, the reliability fell off very sharply. Similar results were obtained from an analysis of the communication contacts between ship and shore stations. No comparative tests on the relative merits of frequency and amplitude modulation were made.

18. The relative merits of amplitude and frequency modulation for radiotelephony on the very high frequencies have recently been considered by a special subcommittee of the Interim Executive Committee of the Radio Technical Commission for Maritime Services (RTCM). RTCM is an organization composed of industry and government representatives having among its objectives the study of existing and proposed systems of aids to navigation and communication to determine their suitability, and the fostering of new developments to meet marine operating requirements. It is planned that RTCM will serve as a means of coordinating government and industry views on matters within its purview and shall formulate recommendations on the basis thereof.

19. The desirability of crystallizing opinion with respect to the relative merits of frequency modulation and amplitude modulation for use in connection with the United States proposal regarding an international frequency for VHF marine radiotelephony resulted in consideration of this subject by the subcommittee even prior to the organization of the RTCM Assembly. This subcommittee recommended that frequency modulation be adopted as standard for the maritime services within the frequency range 30 to 300 megacycles and that this recommendation be forcibly presented in all quarters associated with the problem of international standardization in the maritime service. This recommendation was unanimously adopted by the RTCM Interim Executive Committee. It is, however, subject to review by the final RTCM Executive Committee and, if

approved by that body, will need to be approved by the Department of State before it becomes a part of the accepted United States policy.

20. While the present frequency assignments in the 2-megacycle band now used for safety and navigational communication provide for an exceedingly efficient system, it is recognized that the propagation characteristics of this frequency are not ideal for a large portion of the traffic handled. Considerable interference from skywave is experienced at times on 2182 and 2738 kilocycles due to use of the same channels in other areas. Since these long range interference effects are very much less prevalent on frequencies in the 30-megacycle band and apparently entirely absent on frequencies of the order of 150 megacycles, it is obvious that these very high frequencies are better adapted to short distance communication. Also, an additional interference-reducing effect can be obtained on these higher frequencies by the use of frequency modulation.

21. While reliable communication up to maximum distances of the order of 40 miles (64 kilometers) may be expected on 30 to 40 megacycles with frequency modulation, the range on frequencies in the vicinity of 150 megacycles may be somewhat less. Nevertheless, the range will be sufficient for a fairly large portion of the navigational communication now taking place on 2182 kilocycles.

22. The United States frequency service allocation proposal to be made at the forthcoming International Telecommunications Conference recognizes the potential need for VHF maritime mobile radiotelephone service and the necessity for international agreement on at least one frequency for universal international use if the fullest benefit is to be obtained. The proposal states:

> "The full potentialities of VHF to the maritime mobile service are yet to be realized. Inter-ship, ship-shore and related communication functions can be performed to the full extent required by certain types of small boats, and in part by ocean going ships, whenever they are within range of a VHF coast station. The fullest development will take place if some degree of international standardization is effected. This will allow ships to use the same equipment at any port and facilitate the manufacture and installation of standard equipment with the widest range of use.

"An analysis of the possible future requirements of the maritime mobile service for communications in connection with shore-based radars and harbor control of shipping, safety and distress communications and inter-ship communications on the rivers and lakes as well as the coasts of the various countries has indicated the desirability of standardizing on a discrete frequency in the vicinity of 160 Mc for these possible functions. If standardization is not effected at this conference, it may be difficult later to provide such an assignment because of the anticipated intensive use of very high frequencies by all services. The frequency 156.81 Mc therefore is recommended for universal standardization to be available for the exclusive use of the maritime mobile service for short-range communication."

23. The demonstrated value of radiotelephony for safety and navigational communication on the Great Lakes emphasizes the timely importance of the position taken in the United States proposal with respect to VHF short range maritime mobile radiotelephony for the purposes set forth in the United States proposal.

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INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
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PROGRESS IN RADIO NAVIGATIONAL AIDS

- By -

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ABSTRACT

This paper presents a summary of some electronic systems of Aids to Navigation, including the extent to which they are used and a statement of the possible and probable future need for these systems. The aids are discussed more or less chronologically in the order in which they came into being.

PROGRESS IN RADIO NAVIGATIONAL AIDS

Introduction

1. It is indeed a pleasure to meet and talk with so many persons who are interested in improved radio aids to navigation, particularly so in the case of those who are not necessarily active engineers and scientists but who are concerned with the administrative and operational details of these aids. We, who are concerned with operation, are of course keenly interested in new developments but on the other hand we are not as likely to be carried away with some apparently striking new development because, after all, we are faced with the day to day operation of things that are in physical being and know from experience that it will be years before a proposed development is in operation. It must first be completely tested, operationally proven and finally it must be accepted by the average mariner. In taking this view I have in mind that stern old individualist, the average mariner, who has for years safely navigated his vessel from port to port and is not particularly receptive to anything that might detract from this individualism or rapidly change his well established navigational routine.

2. It is intended that this paper present a summary of some electronic systems of aids to navigation, including the extent to which they are used and my understanding of the possible and probable future need for these systems. Other papers have covered the detailed technical aspects of the problem. The aids will be discussed more or less chronologically in the order in which they came into being, and the discussion will include a statement of the United States attitude regarding certain of these aids.

Radiobeacons

3. The first system that enters into this discussion is the Marine Radiobeacon System of the World. The first radiobeacons in the United States were placed in operation in 1921. The system grew gradually at a rate of 7 or 8 Radiobeacons per year, and now includes approximately 185 Radiobeacons. It is the largest Radiobeacon system in the world operated and maintained by any one country. In the rest of the world there are approximately 400 Radiobeacons.

4. As the number of Radiobeacons in operation increased, the number of Medium Frequency Direction Finder equipments aboard ships also increased. One is dependent on the other. Radio Direction Finders aboard commercial vessels have come to be recognized as an instrument essential to the safety of life and property at sea,

for both safe navigation and for search and rescue. At the present time, United States commercial vessels of 1000 gross tons or over, number about 2900 and approximately 2700 of these are fitted with Radio Direction Finders. These equipments are also extensively used on smaller vessels. Most marine radio manufacturers have standard production models of Radio Direction Finders for all types of vessels. Merchant marine officer personnel are completely familiar with and trained in the use of this instrument and employ it in their daily navigational routine.

5. United States marine Radiobeacons, while not primarily installed for use by aircraft, are available for such use. The United States Coast Guard during 1946 modified 10 of its Radiobeacons located at strategic points in order to make them useful to aircraft, which are already equipped with automatic direction finders, and to encourage manufacturers to produce automatic equipment for shipboard use. The beacons as modified provide continuous carrier operation during the entire transmitting minute, with keyed modulation to provide the identifying characteristic. They were also placed in continuous operation in their assigned sequence - that is to say, one minute on, two minutes off, twenty-four hours daily. Only a minor modification in the control wiring is required to accomplish this type transmission. Reports have indicated that these beacons are useful to aircraft and that they have been used at distances much greater than their advertised range.

6. If history and experience provide any criterion, the new systems of navigation developed during the war will not eliminate the need for the present Radiobeacon system any more than the Radiobeacon system eliminated the need for navigational aid systems that preceded it. The new aids will, within the foreseeable future at least, merely supplement the older systems of navigational aids. The United States Radiobeacon system will be continued and improved.

Shore-based Radio Direction Finders

7. The next system that should perhaps most logically be considered is the shore-based Radio Direction Finder system, for use on both medium and high frequency transmissions. The United States formerly operated about 16 east coast and 14 west coast shore-based medium frequency direction finders as radio navigational aids. This service, except in Alaska, was permanently discontinued in April, 1946. Present plans contemplate the use of shore-based direction finders only for purposes of providing emergency bearings on ships and aircraft in distress in connection with search and rescue. This system, and in fact any system like it in which the equipment ashore determines the data required by the navigator, is subject to saturation, does not give the user an opportunity to evaluate the data.

and involves communication channels. Consequently it is considered undesirable as a general aid to navigation. There are at present, however, about 90 shore-based medium frequency Radio Direction Finders operated as navigational aids by countries other than the United States.

8. High frequency Radio Direction Finder Stations were established during the war as navigational aids primarily for aircraft, for purposes of search and rescue, and for military needs. The United States has not advocated the use of high frequency Radio Direction Finders for navigational purposes, as it is considered that the system does not meet the general requirements of a navigational aid. It has the same limitations mentioned above and, in addition, lacks the accuracy and reliability required for marine navigation.

Depth Finders

9. Depth Finders are mentioned only for the sake of completeness. These equipments being independent of facilities outside the ship require little, if any, governmental or international consideration. They have come to be a standard marine necessity and it is not likely that any device will replace them. We can thank the submarine for providing us with an incentive to direct research toward underwater location. There is now an abundance of technical information in this field and all that remains is to translate this information into the practical commercial instruments for indicating depth, locating fish, examining the ocean bottom or even for investigating salinity and temperature discontinuities along our coasts.

10. It seems appropriate at this time, before proceeding to more elaborate war-developed aids, to plead for a consideration of the needs of small craft. In this regard I not only have in mind the thousands of small craft owners in the United States, but the similar thousands of small craft operators in other countries who cannot afford the instruments required by elaborate radio navigational aid systems. It is true that many of these craft have little need for a radio navigational aid, but there are many, particularly those who operate outside the harbors and headlands, who have a real need for a simple, cheap and reliable all-weather navigational aid. The war research program was directed towards radio navigational aids for large vessels and it appears to me that there remains an exceptionally fruitful field for research and development to provide a navigational device or system suitable for all-weather small craft operations.

Radar

11. You have heard various technical and operational discussions regarding Radar. It is enough for me to say that this electronic device will undoubtedly become as common a sight on the bridge of a ship as a compass.

12. Several United States manufacturers now have production models of Radar available for installation on commercial vessels. About 150 United States commercial vessels have Radar permanently installed and new installations are continuously being made.

13. The lack of a closely regulated commercial Radar program in the United States has held up the marine Radar aid program, but this is not believed to be a serious consideration and in fact may in the end prove to be an advantage. We are not convinced that there is a great commercial need for a complicated marine Radar aid system and even though some need may exist there has been no indication that the United States shipping industry is ready to bear the added burden imposed by increased Radar cost due to the addition of components necessary to take advantage of such a system. If a simple system can be found to fill the need, then both the government and the shipping industry will be spared considerable expense. Research and development in this field have progressed. United States manufacturers, the U. S. Navy and the U. S. Coast Guard have done considerable work in the Radar aid field. Perhaps the most practicable accomplishment was that completed by the Naval Research Laboratory, in cooperation with the U. S. Coast Guard, in obtaining exact quantative data on the reflection characteristics of various types of U. S. Buoys and at the same time obtaining the reflection characteristics of various types of Radar reflectors. This data, properly evaluated, has given us information on which to design our future buoys and Radar reflectors.

14. The United States has recognized the potentialities of harbor control Radar for use in congested areas. We will watch, with interest, the progress in this field that will be made by the installation of a harbor control Radar in the port of Liverpool during the coming year.

Loran

15. The technical and operational considerations of the Loran system have been too well covered by others to require further discussion here. It might be repeated, however, that this system is the only long range navigational system that is extensively used over a world-wide area by air and surface vessels.

16. Fortunately, Loran came into being during the early part of the war, and under the pressure of our enemies we were forced to standardize on a system that appeared to our Military Commanders, Engineers and Scientists to hold the most promise for success as a long range navigational aid. There has been no development since to indicate that we made a bad choice. However, since the war other considerations have arisen with the result that little progress has been made toward peacetime standardization, which standardization was actually an accomplished fact during the war. We in the United States have attempted to preserve this navigational system, as we are firmly convinced that due to the press of several factors (one of which we are all well aware of and that is the world lack of funds and coordinated technical effort) there will not be, in the immediately foreseeable future, another world-wide system installed and placed in operation. In addition, the tremendous effort necessary to develop the technical know-how and to re-educate our maritime personnel in the use, operation and vagaries of other systems, will hardly be forthcoming under peacetime conditions.

17. Loran has several desirable characteristics for world-wide use. It fits well into the scheme of world geodetic charting and in fact a large amount of the basic charting work is already accomplished. It lends itself well to international arrangements, and if required, operation of stations on the same rates in different countries presents no serious difficulties as exemplified by joint Canadian-United States operated stations. There is a considerable amount of war surplus equipment in existence including shore station, shipboard and aircraft equipment. While this equipment is not in all respects satisfactory, a tremendous amount of service can still be had with no further expenditure of world effort and funds. A start has been made by PICAO which can well serve as an example as to how international arrangements might be made to provide coverage over areas where the predominant surface and air routes are used by a group of countries.

18. Innumerable manufacturers throughout the world have facilities suitable for the manufacture of Loran equipment, particularly the shipboard and aircraft receiver indicators. The Honorary Chairman of this meeting has given you assurances regarding technical barriers and patent restrictions. The United States Coast Guard has developed a comprehensive set of System Engineering Instructions which can be made available to interested countries. These instructions are straightforward, tried and proved, and can be followed by any competent electronics engineer. A simplified operational test procedure has been evolved which will readily locate and remove system errors. All of this technical knowledge is available for world use.

19. In summary, a world Loran system is in existence; the war has provided many of us with experience and training on how to use this system; engineering and technical knowledge if not already on hand is available for the asking; there is already in existence equipment for reorientation and readjustment of the system for peacetime use; and a great part of the world is already charted for use of Loran. It is my opinion that we would be unwise indeed to deny ourselves the use of these existing facilities in the hope that at some future date a more completely satisfactory system might be installed.

Decca

20. A complete technical and operational discussion of the Decca System has been presented by representatives of the United Kingdom. It appears that the operational tests conducted in the vicinity of the British Isles have been highly successful and that some progress has been made in resolving the lane identification problem inherent in this system. There seems to be no question as to the accuracy of this system once this problem has been resolved.

21. We in the United States have carefully studied the application of this system to our needs and have met with some questions which should be mentioned for further thought by those members of this meeting who might be forced to consider these same questions due to a similar order of things in their home countries. We have long coast lines, bordering in most cases upon the open oceans. Ships arriving at our ports from other countries and in many cases from port to port within the United States must enter our navigation systems from fixes determined well out at sea. On the other hand the area where the Decca system has been used lies in the center of a series of shipping routes from Northern and North Western Europe. Ships entering the British radio navigational aid systems from these areas are able to do so from highly accurate departures on fixed visual aids. Much of our coastline and surrounding areas well out to sea are covered with fog for days at a time during certain seasons of the year. We cannot use a medium distance system that cannot be positively entered from a dead reckoning position well out at sea. Further, a critical examination shows that a considerable number of medium range navigational systems is required to give complete coastal coverage. This is exemplified by the large number of Radio Beacons in use in the United States. Some of the critical requirements of the Decca systems are that the system must be in continuous operation - that is, it cannot be used on a time shared basis as is the case with radiobeacons, and it cannot tolerate interference on the same frequency. In the case of Radiobeacons, many of these are placed

on the same frequency by making a careful choice of areas and radiated powers and even though some interference might occasionally occur, it is not fatal to the system as is the case with Decca. For these reasons it appears that we in the United States must choose the somewhat less accurate Radiobeacon system to serve our medium distance aid requirements, well knowing that in doing so we are sacrificing the extremely high accuracy that might be obtained with the Decca system.

Summary

22. There are numerous other systems which might be discussed. However, other papers have completely covered these systems and I believe it is obvious to all of you why they have not been advocated by the United States for world-wide use. We are well aware that some of those aids have appeal for local use, where a particular set of circumstances indicate their use. However, we do not believe that the advantages gained in such cases would outweigh the advantage of having a standardized world system of Radio Aids to Navigation.

23. It appears to me, from a purely operational and practical standpoint, that Providence has set a limit on the amount of overall navigational usefulness which we can extract from any radio navigational aid system. In the end it is at best a compromise as to which choice we make. In the case of Loran we increase the amount of shipboard equipment to obtain additional accuracy, reliability and range, whereas in Consol we reduce the amount of shipboard equipment at a sacrifice of accuracy and acceptance of the somewhat dangerous practice of using communication receivers, removed from the bridge of the ship and not under the direct control of navigating personnel. In the case of Decca we obtain high accuracy at the expense of introducing lane identification, which again requires additional shore station equipment and shipboard components to resolve the difficulty. In the case of Radiobeacons we sacrifice some accuracy to gain a wide use of the system on long shore lines by means of shared time and frequency. I believe that this clearly indicates the way that we must proceed in the consideration of World Radio Aids to Navigation. We must at best reach a compromise. Above all we must bear in mind that should we fail to agree we will deny marine and air transportation an opportunity to utilize the tremendous technical developments that have been made in this field.

EARL G. ROSE
REAR ADMIRAL, USCG
CHIEF, OFFICE OF OPERATIONS
U. S. COAST GUARD

all over the world, no matter to what country a ship belongs or in what trade it is engaged.

Last summer we installed our first radar equipment, purchased by the ship owners in the United Steamship Company service, in ships covering the route Esbjerg-Harwich regularly. This summer we shall have 40 merchant ships voluntarily equipped by ship owners with radar installations. We are now operating a Loran Station in the Faeroe Islands and shall have four Decca stations working in Denmark by the close of 1947. It is probably the first time in history that such equipment has been installed on a purely mercantile basis. Locations of the stations are being determined at the present time, and it is proposed that they will cover an area over the eastern and southern part of the North Sea with connections with the United Kingdom chain, a distance along the west coast of Norway, Oslo Firth, Kattegat, and the Danish water passages, as well as the Baltic Sea from Kiel Bay to Gotland. It is to be hoped this installation will be of great use in the important traffic between the North Sea and the Baltic Sea to Norway and the west coast of Sweden. This internationally crowded waterway offers landfall from the open sea through the coastal waters to the navigation of narrow waters and entrance into harbors, and the experiences gained here will probably have great significance in the future development of radio navigation.

There are 35 radiobeacons in Denmark, either operated by or under the supervision of the Lighthouse Department, and we have established the point of view of considering Loran and Decca transmitting stations as a development of radiobeacons. It is therefore the Danish Lighthouse Department which operates the Loran Station in the Faeroe Islands, and it is the Lighthouse Department that will be the Danish authority, in cooperation with the Danish Subsidiary of Decca, which will have supervision of the operation of the transmitting stations. The Danish Hydrographic Department has a trained staff and machines for the computation and plotting of Decca position lines, and it is intended that the Danish Hydrographic Department shall publish and sell maritime charts with the Decca lattice overprinted.

Denmark, furthermore, has purchased three transportable Decca transmitting stations for use in marine surveys on the western side of Greenland. They are at present being tested in Denmark and will be transported to Greenland about July 1 for installation on a trial basis. We expect to be able to begin the actual survey next summer (1948). These stations are being established on lonely, uninhabited, rocky islands or desolate, rocky archipelagoes. All-inclusive supplies, even drinking water and accommodations, must be brought by the survey ship, so it will be understood that careful planning is required for this area alone. Everything must be prepared

in great detail, as for a polar expedition. The Danish Geodetic Institute, during the years between the two wars, worked a system of triangulation from about 60 degrees north latitude to about 75 degrees north latitude, a distance covering inaccessible areas along the west coast but thereby laying the foundation for the marine surveyor. When these surveys were made no one was aware of Decca's precision possibilities; hence the survey method, which at that time seemed entirely sufficient, probably does not equal the accuracy obtained with Decca. Hazy weather is very common in the Greenland waters. The surveying season is approximately but 3 months long, during which time it is almost always light, day and night. Under these conditions, with no modern radio aid (only the old method of surveying), even with an up-to-date survey ship especially equipped in 1935 for this purpose, we estimated it would require approximately 100 years to get these tremendous areas surveyed so that echo soundings can be used and navigation of outlying islands can be undertaken.

In 1938 I went to Greenland on this ship, and the summer passed with attempts to determine the location of the survey ship by radio direction finding from shore-based transportable radio direction finding stations. Instruments to take bearings with the desired accuracy were provided and deviation could be determined with accuracy by simultaneous visual and radio direction finder observations by the survey ship from the shore-based station, but the deviation unfortunately appeared unstable, varying with the soil's conductivity.

In 1939, on the only Danish rocky island, Borzholm, we tried to stabilize this deviation by placing a copper net with a large mesh as compensation under the station. Deviations then became much more stable, and we had great expectations of being able to carry the system through—to pioneer in this field of surveying. We hoped to be able to reduce the period of survey to considerably less than 100 years; but then the war came, with the subsequent occupation of Denmark, and the development of radio aids progressed rapidly overseas.

With Decca to determine locations during survey and Radar as security against collision with the many icebergs, we contemplate the possibility of a 24-hour work-day by the survey ship under all weather conditions except storm periods and that the season possibly can be extended even to some of the darker months!

With these aids we hope to be able to reduce the period of survey to less than 20 years.

Inspired by Mr. Jansky's lecture on the applications of marine radio to lake, river, and passage areas, which in many respects

resemble the Danish waterways and the Baltic Sea, I have prepared this statement. The figures I have quoted here are my own, but I believe they are correct.

As a remark in passing, I should think that these areas might provide splendid experimental ground, should the United States desire to gain experience with regard to the application of the Decca System on this side of the North Atlantic.

As far as experience with radar is concerned, I think that any discussion about the system's applicability for navigation is superfluous. The question is only to produce radar of the highest standard, as simple in operation as possible, and with a minimum of care and maintenance requirements on board ship so that radar will, as in the case of the gyrocompass and echo sounding, in a manner of speaking, take care of itself. The technical maintenance and inspection can be left to shore-based technical personnel during the ship's stay in port. It is my hope that the world soon will be covered by service stations, and I will express the optimistic thought that the manufacturers of radar, with regard to efficiency rather than to competition, will mutually share and thereby make possible the increase in numbers of ports with skilled personnel, affording shipping the necessary service in port for all radio navigational aids, including gyrocompass, echo sounding equipment, etc., so that reliability is increased and the desire of shipping companies to purchase these aids is encouraged. It should be to the interest of the manufacturers themselves to further and coordinate such a port service.

When the competing oil companies can create such a coordinated service system for air as "INTAVA", the manufacturers of radio technical navigation aids should be able to create something similar.

For me the questions as to whether a ship today should have radar are only:

1. Are the manufacturers able to deliver for the growing demand? The shipping trade has money today and, since it is in itself a foreign currency creating agency, the shipping trade has no great currency difficulties, even in countries with currency restrictions.

2. Whether the owner of a ship should purchase radar is only a question as to whether his ship technically and economically can carry the installation. Shipping is business; therefore it is important to make use of the precious ship as intensively as possible, that is to say, to obtain the greatest possible number of ton-miles per year. Here the

quick turn-about in port also is assisted by shipboard radar, shore-based radar, Decca, etc. We are discussing at this meeting devices to assist us in achieving greatest efficiency in navigation on the shipping route. Every ship owner has an average expense figure for the sea miles navigated by his ship. The sea miles traveled that good navigation equipment can save has, in my opinion, been very much overlooked by the ship owners throughout the years, though possibly confused by the effects of wind and weather. Against the background of the enormous sums of money which are spent is the comparatively poor quality of the equipment aboard a ship, which is apparent as soon as one comes on the bridge. It has been striking throughout the years. I am convinced that the ship owners, during the period between the two wars, lost thousands of navigated sea miles by not installing a gyrocompass, which, every day at sea and especially in bad weather with the wind coming in from astern, will save several sea miles by better steering, more certain calculations, and more economical use of the means of propulsion. I wish that the ship owners would be more alert after this war to increase their earning possibilities by the full use of the things we are discussing here. Let us go as far down as to ships from 2000 to 5000 tons, with a roughly estimated mile price of $5.00, according to the type of ship, speed, etc. If radar can save an average of only 1 to 2 sea miles per day--and that is probably a low estimate--it has, on a basis of 200 sailing days, paid for itself for a year. On the larger high-speed ships the period is much shorter--for the QUEEN ELIZABETH, probably only 2 days; and for smaller ships it pays for itself in 2 to 5 years. Therefore, ship owner, by all means buy today! In a year or less you can afford to discard the set and buy a better one if it can be obtained, and you will have gained experience all the time. Certainly the time of arrival is a great economic factor in competition and a saving with the harbor facilities.

Security against collision and running aground creates safety for human life at sea and security against operational losses and upholds the shipping company's reputation for safety.

The greatly increased security should make it possible to decrease insurance premiums, even if the more intensive operation of the ships with the new aids will, perhaps, not decrease the risk as much as a more superficial view might tempt one to think. It has been said that the insurance companies may sometimes wish for damage when decreasing risk percentages force them to decrease

premiums. Lower premiums give a small turn-over for insurance companies, and that is always discouraging in their business. But I hope that insurance companies will not demand too many statistics before reducing premiums, for ships with effective electronic navigation equipment can become a reality. I hope that the insurance companies, optimistically, by a rapid reduction of these premiums, will assist in furthering the installation of these instruments and, by that means, assist in promoting speed, safety, and economy in international transportation.

For use in the coming discussion I should like to request that the following questions be put on the agenda so that we can get an expression of opinion from the two countries with the greatest experience and authority in these fields, the United States and the United Kingdom.

1. Is it conceivable that the competition in the future will produce radar of an inferior quality so that control is desirable in this field, or can we, as by gyro, echo sounding, etc., figure that this apparatus in itself demands such a high standard that the manufacture of radar of inferior quality is not to be considered probable? There is, however, one thing by which the old aids differ from radar. Poor functioning of this older apparatus carries with it only increased risk for one's own ship, while poor functioning of radar, in addition, carries with it risk for other ships. For example, a captain, who comes from a ship with good radar will, if he comes to a ship with poor radar, use this with the same confidence until catastrophe strikes him and, eventually, others.

   I am of the opinion that the freedom as to purchase, sale, and installation, which now is prevalent, should be continued unless there are weighty reasons against it.

   Although my name annually is affixed to 10,000 Danish certificates for ships' lights and compasses, I suppose certificates may also be necessary for radar.

   Furthermore, perhaps in the future, when the time is ripe, it is conceivable that radar may be ordered by governments for ships of a certain size or a certain category, as is now the case with general ship radio transmitters and direction finders. But I am of the opinion that one should let development take its course until experience has shown conclusively that there is a basis for such compulsory measures.

2. Provided control is considered desirable, will the countries which manufacture radar take upon themselves the eventual issuance of a certificate or license so that governments and ship owners, through an order to permit only the installation of radar with a recognized certificate or license, can protect themselves against the use of a poor radar set? Such an arrangement seems most expedient to me, since many countries for several years to come will not have technical organizations which can undertake to make such a certificate evaluation with authority.

3. Will it be desirable for the service personnel to have a special radar certificate? I say "No". We should endeavor to make the apparatus so simple in its application on board ship that the use of the apparatus necessitates only limited instruction during the initial assignment or replacement of the ship's officers so that it can be used by the generally trained (in the future, probably the more "electrically-trained") navigator without increasing the crew or taking similar measures.

   As mentioned previously, I consider it most expedient to leave the care and maintenance to the extensive port service which it is to be hoped will be in existence before long. I think that personnel whose main task is general ship service, including radio service, by and large will do more damage than good if they attempt maintenance repairs beyond the simple replacement of vacuum tubes, fuses, etc. Such minor repairs probably will not call for much training.

I shall close my statement with some brief, practical radar experiences. Our first installation was, as mentioned, placed in the CROWN PRINCE FREDERICK, which, together with the other boat serving the Esbjerg-Harwich route, has radar and Decca aboard. With these instruments the route is considered much safer than before. The master makes the difficult entrance to the harbor at Esbjerg and brings his ship near the pier by use of radar. Along the low sandy coast the Danish Lighthouse Department at present is placing corner reflectors, constructed in Denmark, at six points on shore in the vicinity of Esbjerg Harbor and three on light buoys for further radar aid in sailing into this important trading port.

Another of the United Steamship vessels sails every night during six days of the week at a speed of 18 knots between Copenhagen and Oslo. The Captain sails safely by his radar, guided through Oeresund's gentle, smiling waters, along the Swedish coast and through Oslo Firth's narrow, rock-strewn passage. The Captain

says that he would rather give up his gyrocompass or, possibly, his echo sounding device than be without his radar. Through a very narrow passage with unseen dangers he sails safely by his radar. Last winter when the route was covered by ice floes, the radar worked safely over the ice and picked up the mine-strewn route's iron buoys, which only periodically emerged from the ice floes. The Captain was able to do this safely without confusing the buoys with ice crevices which had formed in the ice floes and which also gave radar reflections.

A Danish pilot who pilots from the Skaw to Copenhagen took, during our severe 3-months winter, approximately 40 ships from the Skaw to Copenhagen without an icebreaker, and he says that his Liberty ship's radar made it possible for him to bring his ice convoys speedily and in relative safety through the mine-strewn routes. He is, as a matter of fact, a brother of a man well known to the Coast Guard, Captain Knud Hansen, who over here during the war trained so many United States Coast Guard Cadets on the Danish Training Ship DENMARK. I received the report from Captain Hansen upon his return from his winter training trip to Seattle.

A pilot can, therefore, immediately make full use of radar when he can get on board a ship with this equipment.

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
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A PREVIEW OF SOME UNITED STATES NAVIGATIONAL AID DEVELOPMENTS

- by -

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ABSTRACT

This paper, prophetic in nature, presents a descriptive summary of some of the systems and devices which, while not included among the systems covered by official United States Policy, are in various stages of development in this country.

These systems and devices are: LF Omni-directional Radio Range, Navaglobe, Teleran, Lanac, DME, and Radar Camera.

The point is stressed that while we should standardize and use now what we have now, we must not be blind to newer developments for possible future use.

A PREVIEW OF SOME UNITED STATES NAVIGATIONAL AID DEVELOPMENTS

Introductory

1. Man's quest for ultimate perfection is relentless. That is wholesome. That is desirable.

2. Progress is a going forward in the direction of ultimate perfection. If there is one prerequisite for progress, that prerequisite is openminded inquisitiveness. Let us be ever inquisitive about potential solutions to present problems. Let us ever be openminded about those potential solutions, for I am sure we do not wish to return to the dark ages, not even to its shadows.

3. In the field of marine radio aids to navigation, we all seek better systems better to serve the mariner. We seek systems which cost less to install and operate. We seek systems which are more accurate. We seek foolproof systems. Systems which are automatic, if you will. Systems which require little or no training on the part of those who are to use them. Systems which possess the utmost in reliability, and systems which require the barest minimum of radio frequency spectrum space. Systems which lend themselves readily to standardization.

4. I am sure that we here are together on these attitudes.

5. We in the United States recognize full well that some day the mariner will be given something better in the way of radio aids to navigation. In fact our Policy states that "An openminded attitude shall be maintained toward novel systems and devices which eventually may develop to be superior to existing systems. This attitude, however, shall not be permitted to retard the adoption of a world system based on systems already proved and in wide use over a large part of the world's waterways."

6. The distinction in this policy as between adoption now of systems already proved and the recognition that the future will bring superior systems is sound. The work of the world cannot await the ultimate system but must be done now with what we have now.

7. Other speakers have discussed with you the adoption of a world system based on facilities already proved and in wide use. But let us not be blind to the future. It is my purpose here to give you a brief descriptive preview of some of the navigational aid developments which continuing scientific and technical research in this country is unfolding. While these have been developed for aviation they have possible application for marine use.

LF Omni-Directional Radio Range

8. The low frequency omni-directional radio range developed by the Civil Aeronautics Administration, the United States governmental organization which operates air navigational aids over airways in this country, is a narrow band CW radial track system designed for use as a long-distance air navigational aid. A low-powered station has been built and tested near Indianapolis, Indiana. Flight tests indicate good performance free from attitude or other similar effects within the service area and, using a full scale (left to right) course indication of 10 degrees, twice as sharp as that used on the VHF omni-directional range. In principle, this range operates in a manner similar to the VHF omni-directional radio range now being installed on the Federal Airways of the United States and utilizes the same simple azimuth selector and left-right indicator, or the same automatic bearing indicator.

9. A high-powered station is being installed at Nantucket Island, Massachusetts, for a service test of the system over both land and water. The antenna system at Nantucket Island consists of five 300 foot, self-supporting steel towers, one at each of the four corners of a square with one in the center. The corner radiators are spaced 600 feet on the diagonal. The opposite radiators will be excited in phase opposition and are referred to as a pair. Available equipment has limited the Nantucket Island station center tower power input to approximately 4 kilowatts on a frequency in the vicinity of 200 kilocycles.

10. The azimuth from the station is determined by the measurement of the phase of the 30 cycle per second modulation. In order to measure the phase of the 30 cycle per second signal called the "variable phase signal", a "reference phase signal" is radiated in all directions at the same phase from the center antenna. This low frequency omni-directional range is based on the principle of the measurement of the phase of a 30 cycle per second modulation and should not be confused with systems which measure the phase of radio frequency carriers.

11. The pilot, without assistance, may use this navigational aid in two ways:

(1) By rotating the azimuth selector until the indicating instrument needle is centered, the pilot has available a course to or from the range station.

(2) By centering the needle on two different omni-directional range stations, a fix may be plotted using the two bearings obtained.

12. From the flight tests and theoretical considerations it appears that the low frequency omni-directional range may possess exceptionally good flight characteristics and, when operated at high power with adequately high antenna towers, presents a possible solution to the long-range aircraft navigational problem.

13. Whether this system will meet the needs of the surface navigator remains to be demonstrated.

Navaglobe (Long-Range System of Navigation over Oceans and Continents)

14. The Navaglobe radio navigational system, under development by the Federal Telecommunications Laboratories, (a unit of the International Telephone and Telegraph Corporation), as a long distance aviation aid, may also have its application as a marine aid. Work on the construction of an experimental Navaglobe transmitting station and associated receiving and indicating equipment is currently in progress. Indications are that the first experimental trials of the system may begin during the latter part of 1947. At the present time, therefore, no experimental data on performance can be given.

15. Navaglobe would use frequencies in the low frequency portion of the spectrum. Frequency stability in the transmitter and in the receiver is said to permit the use of the extremely narrow radio frequency band width of twenty cycles per second. Transmitter power would be from 5 to 30 kilowatts depending upon the latitude.

16. The Navaglobe system is essentially a low frequency CW omni-directional range. The ground station makes use of three antennas disposed in an equilateral triangle. Only two of these antennas are used at one time. Each pair produces a separate radiation pattern.

17. The omni-directional range of Navaglobe operates by the amplitude comparison principle. Instead of using only the equal-signal line, however, the range receiver is adapted to measure accurately the ratios of successive signals by a succession of three-coil ratio-meters. This renders it possible to identify radio paths for

amplitude ratios other than unity. Instead of comparing the amplitude of these signals, three successive signals are radiated plus an initial synchronizing signal. The whole cycle takes place once per sedond.

18. Signals in the aircraft or ship are received by a very narrow band receiver equipment with a special three-coil azimuth indicator. The narrow band receiver makes use of a shielded loop antenna. Advantage is taken of the loop directive pattern additionally to provide an automatic direction finder indication in the aircraft or ship. Both the azimuth meter indication provided according to the omni-directional range principle and the bearing indication provided by the automatic direction finder principle are fully automatic.

19. The principles of a "fine" version of a Navaglobe type system have been worked out. It has been indicated that accuracy would be some six times better than that of the standard Navaglobe system discussed above. The "fine" system uses a different type ground station but the mobile installation would use the same receiver and indicator, plus some minor adapting equipment. The selector switch would allow readings to be made either on standard or on "fine" Navaglobe stations as desired or as available.

20. While no experimental data on performance are available, the manufacturer states that numerous studies indicate that the accuracy of the system, when perfected, may be expected to be one degree on the bearing of the receiver from the ground station. At a distance of 300 miles the lateral accuracy is stated to be 5.1 miles and becomes progressively less until at 10 miles it is said to be in the order of 300 yards.

Teleran (Television and Radar for Air Navigation)

21. Teleran derives its name from the combination of TELEvision and Radar for Air Navigation. The system is under development by Radio Corporation of America. While Teleran itself is not recommended by the manufacturer as a navigational aid for surface vessels, marine interests may find very stimulating the use of television in the application of radar in that field.

22. Essentially, this system employs a ground search radar which surveys the air space of interest and displays on a cathode ray tube the information thus received. This ground radar presentation, superimposed on a map of the area if desired, is viewed by a television camera, and the combination picture is broadcast by a television transmitter. The picture is reproduced by a television receiver in the airplane. The pilot sees his plane as a

spot of light moving across the map. Other planes appear as different spots of light, each moving according to its actual course.

23. In addition to transmitting precise radar information to aircraft, television provides a means for transmitting other data, such as weather maps, ceiling and visibility data, and traffic instructions. Rather than being "instrumental" in nature, the received information is "pictorial".

24. A simulated Teleran display has been installed at the laboratories of Radio Corporation of America. During the fall of 1947 flight tests are scheduled with an airway Teleran station, an airport surveillance station, and a landing system in the vicinity of Washington. A television display tube has been developed having sufficient intensity to permit the reception of pictures in full daylight, such as might be experienced in the cockpit of an aircraft flying above the overcast. The Teleran system with the azimuthal radar scan and the transponder response lends itself quite naturally to techniques of automatic flight and automatic landing.

25. Teleran is considered as a future system. Additional work unquestionally remains to be done. The program is, however, proceeding.

Lanac (Laminar Navigation and Anti-Collision)

26. Lanac--which stands for LAminar Navigation and Anti-Collision--is a navigation, anti-collision, traffic-control, and rescue system which proposes to use frequencies in the order of 1000 Mc, low power, pulse transmitters and receivers with associated scope displays intended to permit the safe and expeditious movement of vessels and aircraft alike under all weather conditions. The range of the system is approximately line-of-sight. Developed and tested by the Hazeltine Electronics Corporation, Lanac is a commercial outgrowth of the Identification, Friend or Foe (IFF) systems used for the rapid identification of friendly ships and planes during the war. As such it affords the automatic identification of all cooperating craft and beacons.

27. In the major functions of the system, the challenger sends out a series of coded "challenge" pulses from a directional antenna to the replier at the distant target. There, if properly coded and transmitted on the proper radio frequency, the challenge pulses succeed in "triggering" the replier, which then

automatically identifies itself by transmitting a series of Morse-coded "reply" pulses in all directions. The challenger receiver picks up these replies and feeds them to a display console where the target's distance, direction, and identity are instantly shown to the operator.

28. In the anti-collision (and traffic control) service the signals from all repliers within range (except the exclusively navigational beacons) appear on the scope at once. The challenger also can operate as a conventional low-power radar, thus affording collision protection when such obstacles as icebergs, floating hulks, fixed hazards, or other vessels without repliers are concerned. Harbor traffic control for busy fog-bound ports, is one marine service in which Lanac may prove especially useful. Lanac equipment would enable ships in the open sea to exchange position reports automatically with passing vessels and trans-ocean aircraft.

29. For rescue work, all Lanac ship and aircraft repliers are capable of transmitting distinctive signals that indicate distress to other Lanac equipped craft and small, portable repliers—weighing less than 30 pounds—may be used as rescue beacons on lifeboats or rafts. The distress signal has the same meaning as an SOS, and is received by all ship, shore, and aircraft challenger-receivers within range. Distress operation is automatic, like all other replier functions. The rescue beacons enable searchers in ships or planes to "home" directly on a speck in the ocean that might not be seen by either radar or the naked eye except at close ranges.

<u>DME (Distance Measuring Equipment)</u>

30. Distance Measuring Equipment (DME) utilizes low-power, pulse transmitters, and receivers with associated meter displays to simplify the navigation of vessels and aircraft alike under all weather conditions. A commercial outgrowth of wartime IFF, this system provides the navigator with a continuous indication of his range from a self-identified beacon. The maximum range of this system is normally line-of-sight.

31. The DME system, operating in the vicinity of 1000 megacycles, consists of a radio transmitter-receiver, called the "challenger", installed in a ship or aircraft and a radio receiver-transmitter, called the "replier", installed on the shore or ground. The challenger initiates the sequence of events by continuously transmitting a stream of coded radio frequency pulses in all directions

from its omni-directional antenna. The challenging signal is received by the DME replier beacon and a decoder unit in the replier determines whether to accept the challenge. If the code of the challenging signal is the code for which the replier's decoder is set, the replier accepts the challenge and transmits a reply. The reply is a stream of radio frequency pulses which carry the beacon identification letters in code. The reply is received by the challenger and provides information for the display of the range and identity of the beacon on the challenger distance meter.

32. Some of the desirable features of the DME system are its almost completely automatic operation, continuous presentation of distance to the ground beacon, minimum interference from extraneous signals, and traffic handling capability.

33. Interference from extraneous signals is minimized by multifrequency operation and pulse coding. The challenge and the reply are on different frequencies, therefore neither reflected signals from the challenge pulse, nor the challenge pulse itself can cause erroneous readings on the distance meter. Assignment of different frequencies to beacons in the same area will reduce the possibility of a reply from any but the desired beacon.

34. Fifty or more DME challengers are able to obtain reliable signals from the same beacon.

35. In operation, the DME system requires the installation of several replier beacons at harbor entrances, channel entrances, and at strategic points along the coast. Ultimately the system could be expanded to equip completely the coast so that two beacons would always be within range. For harbor approach and navigation in restricted waters more numerous beacon locations afford highly accurate three-point fixes.

36. DME repliers installed in weather ships stationed at specified positions near the trans-ocean sea lanes would serve as convenient navigational aids when fixes using celestial observations cannot be made.

37. Employing a hand- or battery-operated replier emitting a characteristic emergency signal, the DME system can be used in air-sea search and rescue work. The hand-powered model may be used in guiding a ship or airplane to a lifeboat or aircraft can drop battery-powered sets in the vicinity of a liferaft.

38. The DME system for air navigation was operationally demonstrated at the conference of the Provisional International Civil Aviation Organization (PICAO) in October 1946, at Indianapolis. Since that time production contracts have been let for the initial procurement of 1000 megacycle DME beacons for airway installations.

Radar Camera

39. An interesting accessory to radar is a camera which simultaneously and automatically records radar images, range setting, time, an exposure counter, and hand-written information on each picture. The radar scope is viewed simultaneously by the operator and the camera without interference. The images are recorded on standard 35 millimeter moving picture film and the operation of the camera is controlled by the scanning rate of the radar receiver. Either PPI or sector scan is recorded and the images obtained are sharper than those seen with the naked eye because only the instantaneous trace is recorded.

40. The usefulness of radar may thus be extended by this permanent record, and because the photographic image is sharp and is automatically recorded, this camera is useful for radar charting of harbors and inland waterways; permanent recording of vessel relationships in congested waters during conditions of poor visibility which becomes useful evidence in the event of legal action; and recording weather phenomena.

41. The camera unit can be adapted to meet special requirements and can be installed on standard radar receivers. Perhaps the most useful installation is made on a repeater scope. By means of this installation, it is possible to record compass heading, engine telegraph, revolutions per minute, whistle signals, and other data on the same photograph with the radar information.

42. Radar charts for commercial airlines are now being prepared from photographs made with such cameras. Shipping organizations will undoubtedly find this camera a useful extension of their use of radar. During the course of this meeting, one of these cameras made by Fairchild Camera and Instrument Company will be demonstrated.

43. I have tried to give you a brief description of some of the systems and devices under development in this country which may have direct or indirect application in the marine service. Should

you desire further details on these and perhaps other potential systems and devices, you may wish to refer to those papers which will be made available but not read to you.

44. With regard to frequency service allocations for the radio systems and devices mentioned above, it should be noted that, while we are not sponsoring these systems and devices now for marine use, the United States allocation proposals being presented to the International Telecommunications Conference this month do not preclude their adoption in the future, provided of course that only one system were to be standardized in the bands mentioned.

Summary and Conclusion

45. There are numerous other systems and devices which have been conceived in this country and which are now in various stages of development. Time does not permit my describing them here. Undoubtedly others, novel, unique, and radical will come along in the future.

46. To conclude, we must continue to forge ahead, work with the mariner, try to give him what he needs insofar as the radio art can fill his needs.

47. But a word of caution. Let us not be too hasty in the adoption and standardization of new systems and devices. They should, in the final analysis, be tried, tested, and proved operationally by the mariner himself. . . . . . Thank you.

E. M. WEBSTER
COMMISSIONER
FEDERAL COMMUNICATIONS COMMISSION

IMMRAN DOC. 35

U.K.PAPER NO. 18

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION

NEW YORK CITY AND NEW LONDON, CONN · · · APRIL 28 - MAY 9, 1947

A CENTIMETRIC ROTATING BEACON

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SUMMARY:

Some progress has been made in the development of a centimetric rotating beacon, which transmits bearing data during rotation of the aerial, and of the associated ship receiver, which displays the bearing information on a calibrated scale. Preliminary trials have given promising results, and trials with improved receiving apparatus are planned for April 1947.

The beacon can also be used as a part of a distance measuring system, enabling meter display of both range and bearing to be obtained with comparatively simple shipborne equipment.

A CENTIMETRIC ROTATING BEACON

1. The desirability of the provision at suitable sites in the vicinity of dangers to navigation of an improved type of radio beacon, which would enable small craft with simple receiving apparatus to determine a position line or position fix, was stressed at first IMRAMN.

Amongst desirable characteristics of such a beacon the following have been stressed:-

(i) Reasonable accuracy to be obtainable with simple receiving apparatus.

(ii) Simple presentation of data, with minimum skill required for operation or interpretation.

(iii) Freedom from site errors.

(iv) High intrinsic accuracy of data transmission so that a higher standard of accuracy is possible with a more complete receiver.

Facilities of this type are provided by M/F rotating loop beacons of the type installed at Orfordness, but as pointed out at first IMRAMN, the Medium Frequency Band of the spectrum does not give full scope for the development of short-range facilities of this type and frequencies above 100 mc/s are far more appropriate.

At these frequencies the effect of reflections in producing siting errors is of great importance. A monostatic phase beacon has been developed in the 100 - 150 mc/s band which is in use for civil aviation, but a beacon of this type would be unsuitable for marine use in many important water-ways - for example, in the Norwegian fjords.

In order to obtain freedom from siting errors, it is considered essential to use pulse technique, despite the fact that this involves somewhat less simple receiving arrangements than are possible with a phase beacon system.

2. During the past year, some progress has been made with the development of a beacon comprising a pulse modulated centimetric transmitter with a continuously rotating aerial. Bearing data is transmitted as a variation in the pulse modulation. By the use of a centimetric frequency band for transmission, a narrow beam of energy is radiated with an aerial of moderate size capable of rotating at a speed of 60 r.p.m. A coding system has been

developed to enable a number of beacons to operate on the same frequency without mutual interference.

For reception of the beacon transmissions a crystal detector and pulse amplifier is used, with decoding and meter circuits which convert the pulse signals, intermittently received when the receiving aerial is illuminated by the transmitted beam, into a continuous indication of bearing on a calibrated meter. The simplest type of receiving apparatus contains 8 valves, and weighs about 15 lbs.

3. System of Modulation.

The method used for transmitting bearing data is illustrated in Fig. 1. As the aerial rotates two pulses are transmitted, and the time-interval between the pulses is varied during the rotation in proportion to the angular displacement of the aerial beam from North. A third pulse is radiated; the time interval between this pulse and the first is fixed, and exceeds the maximum interval between the first and second pulses by a time equal to the minimum spacing between these pulses. This is a calibration pulse; the inclusion of this pulse in the transmission obviates the necessity for including accurate time or voltage standards in the receiving apparatus.

The transmission of this group of three pulses, called respectively the North (N), Bearing (B) and Calibration (C) pulses, is repeated at a convenient pulse repetition frequency.

In order to minimise the effects of oxtraneous interference, and to enable a number of beacons to be operated on the same radio frequency, each pulse is in practice a double pulse, of characteristic spacing between the two pulses.

Values which have been used during the experimental development as as follows:-

N pulse;	2 pulses each of width 2 microses. spacing 4 microsecs.
B pulse	2 similar pulses with spacing 6 microsecs.
C pulse	2 similar pulses with spacing 8 microsecs.

Interval N - C 300 microsecs.

N - B	60 microsecs at N, varying linearly with azimuth at a rate of 0.5 microsecs/degrees to a maximum of 240 microsecs.

• Pulse group repetition rate — 500 per second.

4. Experimental Beacon.

The experimental beacon has been constructed from an existing transmitter and aerial system, with modulator and submodulator designed to give the required modulation characteristics. The aerial is a parabolic cheese of 40 inches horizontal aperture, giving a beam width of 8 degrees at the operating frequency of about 3300 mc/s. It is rotated at 60 r.p.m. and a DC voltage varying linearly with azimuth to an accuracy of 1 part in 1000, is generated by means of a potentiometer mounted in the pedestal. This voltage controls the N - B pulse interval and the accuracy of data transmission is of the same order. With this system there is no transmission at bearings between 359.5° and 0.5°, i.e. when the arm of the potentiometer passes from the end to the beginning of the winding. The transmitter gives an output of about 15 KW peak to the aerial which has a power gain of about 300X. For convenience during trials the equipment is mounted in a trailer, with the aerial protected by a perspex radome.

5. Reception.

5.1. Principle of Meter Indication.

The principles adopted to convert the bearing data from received signals into pointer deflections is to generate in the receiver rectangular pulses of current of widths proportional to the time-intervals N - B and B - C N-B and N-C. The pointer deflection is then made proportional either to the ratio of the magnitudes of the N.B and BC pulses in one system or to the difference between the N-C and N-B pulses in another. Neither method requires complex circuit arrangements, but much time has been spent in the study of alternative arrangements, with a view to the development of the most economical and the most accurate methods. The most economical method is probably that using a peak voltmeter circuit; the most accurate, one involving the use of a minature split-field, reversible motor. In either case the meter circuits have long-period discharge time constants, so that a continuous indication of bearing is given. On the other hand, a special circuit has been developed to enable the indicator to respond rapidly to changes in bearing.

5.2. Automatic Gain Control.

To ensure automatically that the receiver works only on signals received from the tip of the main lobe of the beam, on automatic gain control circuit is incorporated. This comes into operation when the number of pulse groups received exceeds three, and reduces

receiver sensitivity so that the number of groups received per second never exceeds seven, corresponding to a beam-width of $\pm$ 2-1/2 degrees.

5.3. De-coding.

De-coding circuits have been developed so that the meter circuits are operated only by pulse groups having the assigned spacing between pulses, within narrow limits. By varying these spacing characteristics, a larger number of beacon codes is made available, the desired code being selected by a switch on the receiver. The decoding circuits also give a high degree of protection against unwanted signals, and because they are designed to work on the leading edges of the received pulses, against the effect of reflected signals.

6. Experimental Receiving Equipment.

The receiver used for trials comprises an omnidirectional aerial - a stock of half-wave 2 elements with a power gain of 5, connected by means of a concentric feeder to a crystal detector. The video amplifier has five stages with an overall gain of 100d.b. The decoder circuit has two valves, and one valve is used for automatic gain control. The peak voltmeter meter circuits use four valves.

For convenience in experimenting with meter presentation circuits of various types, the meter circuits are in a separate unit, and the experimental receiver comprises two units, one 7" x 6" x 5", and the other 5" x 4" x 3", with the actual meter as a separate item.

7. Experimental Trials.

Owing to the very limited effort available for this work preliminary trials only have been carried out to date, with the beacon installed at Eastney Fort East, on a site with a number of buildings in the vicinity, and an aerial height of about 40-ft. Owing to the nature of the site reception was possible only over an arc of about 180°. These preliminary trials indicated that the bearing accuracy was limited by characteristics of the indicator used, but that the maximum error observed was $\pm$ 2°. The maximum range at which the receiver was used during the trials was 14 nautical miles, no attempt was made to determine the maximum possible range. Changes in bearing of one degree could be observed. No effects due to reflection were observed, although the buildings in the vicinity of the beacon gave strong reflections on many bearings.

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These results were considered sufficiently promising to justify further development, and arrangements have been made to carry out more extensive trials with improved receiving equipment during April, 1947.

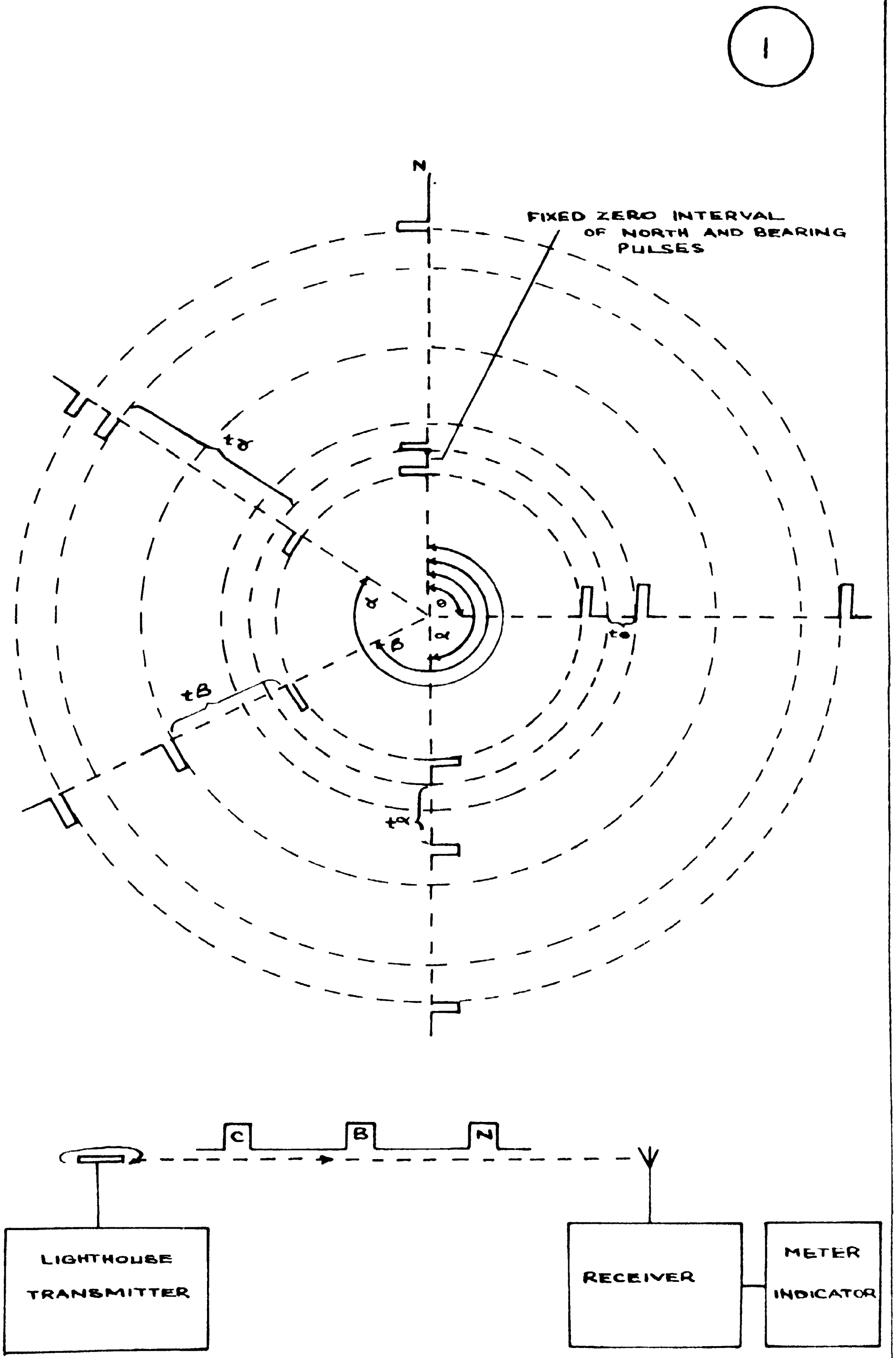
8. Measurement of Range.

A beacon of this type could be used as part of a system giving a position fix, by measurement of range as well as bearing. This extension of the system is illustrated in Fig 2. A low-power UHF interrogator is added to the ship equipment, and a UHF receiver to the beacon. In operation the C pulse is used to unlatch the ship interrogator, which operates at a PRF independent of that of the NBC pulse group. The interrogator pulses are received at the beacon, and used to trigger the beacon transmitter, which emits an "P" pulse group. This pulse group is received on the ship decoded, and used to give display or range on a meter.

It should be noted that a system of this kind has a high saturation level since the interrogator transmits only when the ship is illuminated by the centimetric beam of radiation from the beacon.

Preliminary trials of this system have been carried out, but the effort available is inadequate for further development at present.

April, 1947



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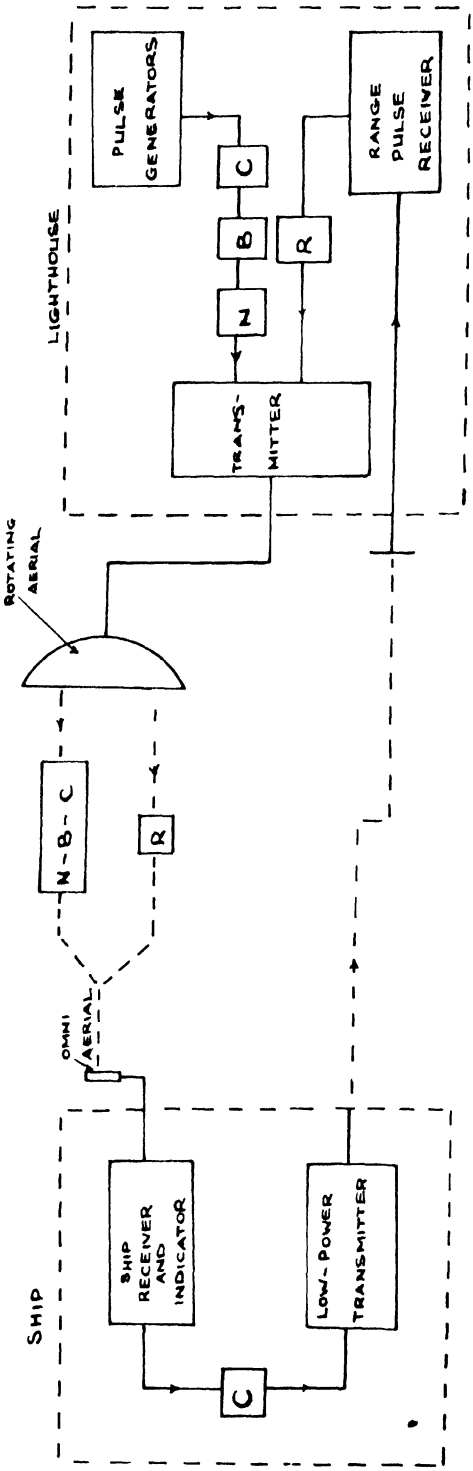

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INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN · · · APRIL 28-MAY 9, 1947

THE SAFETY AT SEA ASPECTS OF TELECOMMUNICATIONS AS REFLECTED BY MARINE RADIO NAVIGATIONAL AIDS

- By -

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ABSTRACT

This paper describes the importance of a complete marine system of international telecommunications for obtaining, exchanging, and disseminating messages concerning navigation and safety at sea. Attention is drawn to the widespread need for transmitting and receiving navigational data in relation to a variety of nautical operations.

Certain undesirable aspects of the existing maritime radio situation are discussed and the need for constructive measures through international cooperation is stressed. The substantial progress already made in necessary world-wide standardization of aviation telecommunications facilities is observed and the advantages to shipping in similarly resolving its international telecommunications problems are suggested.

The maritime radio interests are urged to cooperate as an international group, including the establishment of appropriate liaison with aviation on problems of common interest, in a way to assure organized world-wide progress in efficient frequency spectrum utilization and technical standardization in accordance with the latest advances of science.

THE SAFETY AT SEA ASPECTS OF TELECOMMUNICATIONS AS REFLECTED BY MARINE RADIO NAVIGATIONAL AIDS

1. Most of the preceding papers have drawn attention to some special problem or system of marine radio aids to navigation. It is my purpose to discuss in a general way the principal components of a complete international telecommunication system for safety at sea, with some emphasis on the value of international coordination and standardization in this field.

2. Considering the international definition of the word "telecommunications", as it appears in the Annex to the Madrid Convention I assume that a system of marine "telecommunications" includes radio aids to navigation as well as all necessary facilities for the exchange of two-way communications and for the one-way transmission to ships of information beneficial to mariners. My discussion of this subject will be confined to the application of telecommunications to the needs of ships that are navigated on international voyages in the open sea. This is the marine service in which world-wide standardization, cooperation, and coordination are definitely desirable, if not necessary.

3. In this field, radio, as one medium for transmitting telecommunications, meets two fundamental needs, (1) a need for directly obtaining accurate navigational information, and (2) a need for the exchange and distribution of messages on navigation and safety matters.

4. Let us consider who is it that needs information on navigation, excluding the strictly commercial objectives. Included among them are:

(1) the navigator of the individual vessel when he is concerned only with his own ship. He should know his geographic position at all times, and especially in time of dangerous or hazardous conditions or in the event of sudden and serious illness or bodily injury of persons on board. Also he should have information more or less continuously on weather forecasts in his area of navigation as well as up-to-date reports on obstructions, including other vessels, that may lie in the possible course of his ship, and accurate information on the state of all established navigational aids not in normal working condition and upon which he is likely to rely.

(2) The navigator of the individual vessel when he is concerned with proceeding to the assistance of another ship or survival craft. In addition to a knowledge of his own position, he must know the position of the ship or craft in need of assistance. Weather data at such times also is important.

(3) The navigator of the individual vessel when he is confronted with a situation which may compell him to call for assistance from other vessels. This is indeed vital when it becomes imperative to launch lifeboats and abandon ship. He should have fairly accurate knowledge at such times of those ships which are in a position to come to his aid, as well as information on their course, actual speed and available rate of speed.

(4) Coastal radio stations, in order to most effectively contact individual ships for whom they have messages, involving safety or rescue at sea, should know the location of the respective ships.

(5) Search and Rescue agencies, both shore-based and ocean station vessels, should be informed of the approximate location, course and speed of individual ships at sea in order that the most efficient action can be taken in time of emergency to provide coordinated assistance to a distressed ship or to survival craft from either a surface vessel or an aircraft.

(6) Agencies of the various national governments which collect and disseminate marine and aviation meteorological data, should, insofar as practicable, regularly receive meteorological reports from ships at sea. Such reports, obviously, must include the location of the reporting vessel.

It is observed, therefore, that the need for navigational information is not necessarily confined to the individual mariner, but is rather widespread and is distinctly related to a variety of nautical operations.

5. The use of navigational data to determine the location and to plot the course of an individual ship, when such location and course

are not imparted to other ships or to agencies ashore, is unquestionably important. It is also important, however, to transmit such information, frequently in association with other information, concerning safety of life or property, to other ships, to points on land, and possibly to overseas aircraft. Hence, in considering radio as an aid in the movement of shipping, cognizance must be taken of the strictly communication aspect of marine telecommunications, in addition to the separate radio facilities intended solely for position determination.

6. This meeting has been concerned mainly with radio apparatus for vessel position-finding and for the continuous disclosure of objects within the immediate area of navigation of vessels. While some discussion of related communication facilities has occurred here, the latter subject has received the lesser attention. We cannot emphasize too strongly the over-all safety system of marine telecommunications, including ship-to-ship, ship-to-shore, and point to point communication in connection with the actual position-finding and position indicating devices which have been so well described here.

7. We can more readily understand the desirability for international negotiation to achieve proper integration and coordination of a world-wide marine telecommunications system if we consider that navigation aids remain of limited value without a dependable means of disseminating related information. We must rely upon international negotiation not only to maintain the adequacy of today's system but also to insure that marine telecommunications systems of the world will fully reflect and make available to all maritime interests the advances of science in both communications and navigation aids.

8. We have heard a great deal about the numerous valuable and modern radio devices for aiding the navigation of ships and we expect to see some of them in operation during the next few days. There is a general feeling that we have technically forged ahead in a phenomenal way under a wartime urge and that now we have at our command the unexcelled means to assure the safest possible navigation of ships and the speedy location of distressed vessels even during restricted visibility. It may appear that from now on we need merely to solve the economic problem of manufacturing and supplying the appropriate devices to the ships and installing other necessary equipment at fixed points. Perhaps such an outlook is not altogether realistic. Let us consider briefly some of the undesirable aspects of the present situation and what difficulties may develop if certain aggressive action is not taken by those responsible for the international regulation of marine telecommunication services and systems.

9. We know that the radio frequencies for radio aids to marine navigation must be formally designated and protected from interference on a world-wide international basis. At an earlier session, Commissioner Jett, one of the members of our radio regulatory body in this country, explained the close relationship between the successful international use of the various radio aids and the needed world-wide recognition by the forthcoming International Telecommunications Conference of adequate and specific bands of frequencies to accommodate these aids. If the maritime interests are to secure their required spectrum space on a world-wide basis, they must decide which of the available aids can be standardized, what the standard frequency band requirements will be, and establish their order of preference in the event spectrum space cannot be provided for all of the desired devices and systems. It appears that those navigational aids which can serve both aviation and shipping have the better possibility of international endorsement, from the points of view of spectrum space economy, production cost of apparatus, and smallest operational expense to the administrations who will provide, operate, and maintain the necessary shore-based facilities.

10. Although the existing telecommunication treaty provides certain bands of frequencies for marine radio beacons and shore-based direction-finding services, it does not specifically recognize or give primary protection from interference on any frequencies above 3000 kilocycles for either marine navigational aids or marine communications. In fact there is as yet no world-wide international allocation of the spectrum above 200,000 kilocycles where many of the recently-developed and very valuable navigational aids operate.

11. There are no standardized marine communication frequency bands between 1500 and 30000 kilocycles; neither are there sufficient operating regulations to govern the handling of distress, safety, and navigational messages in these characteristic long-distance bands. We are concerned here with both the telegraph and the telephone services. In this regard, there is need for intercommunication with the aeronautical service in emergencies involving aircraft at sea. A common distress and emergency DF frequency in this band should be agreed upon for aircraft, ships and survival craft.

12. There are no specific and standardized marine frequency bands and prescribed frequency stabilities for the very high and ultra high portion of the spectrum above 30000 kilocycles; also there is need here for standardization on the type of emission for telephony and modulated telegraphy. Shall we use, internationally, frequency modulation or amplitude modulation? Further, we have as yet no agreed international radio operating procedure, including a "Q" code or the

equivalent, to assure the most efficient use of these frequencies for short-distance communication in connection with position-finding and position-indicating devices, as well as for shore-controlled movement of vessels in dense traffic.

13. While the existing International Radio Regulations provide that the use of emergency installations in the maritime service must comply with those Regulations, there is no designation of a standard high frequency or frequencies to be employed for the transmission of distress messages from survival craft at sea. Under the provisions of the Safety of Life at Sea Convention, the radiotelegraph installation of a compulsorily equipped lifeboat need only comply with the individual requirements of the responsible national Administration.

14. The existing International Radio Regulations might well be reviewed with the object of clarifying their provisions relative to the use of a radar transmitter on shipboard for navigational purposes with or without the operational services of a licensed radiotelegraph operator.

15. The permissive use of damped waves by ship stations and the relatively wide frequency tolerances for other types of waves used by ship stations should be reconsidered in reference to the present state of the art. This practice is not conducive to efficient use of the spectrum space available to the maritime service and can well be criticized by those who may not have sympathy for the spectrum needs of this service.

16. Unless these questions are resolved and a unified international position is established by the maritime groups at the forthcoming Radio Administrative Conference, many international problems and attendant negotiations involving interference and confusion in the future use of marine navigational aids will probably result. It would be regretable indeed not to take full advantage of this timely opportunity to materially improve the safety of world-wide shipping. While a commendable degree of progress already has been made through several preliminary international discussions, the final solution has not yet been achieved. Those of us in the United States who are concerned with this work have given very careful thought to the complex international problems involved and we are prepared to state our views in considerable detail. In regard to the spectrum space believed necessary for all of the services of marine telecommunications, the formal proposals of the United States submitted for consideration at the Atlantic City conference speak for themselves.

17. Many factors involved in the standardized operation of internationally useful radio aids to marine navigation are not, in all probability, subjects upon which agreement can best be reached

through a general telecommunications conference. I have reference, for instance, to those radio operational details and procedures that concern and affect the maritime services exclusively and have no relation to other radio services. These are related to and influenced by the characteristic operational problems of international shipping. For instance, there seems to be no world-wide understanding as yet on the services which the shipmasters and the operational shipping authorities might reasonably expect to receive from the use of marine radio facilities ashore and afloat that serve international maritime routes. There may be merit to the adoption of Standard Practices and Recommended Procedures for the Marine Radio Service, which would be of no special interest to any other telecommunications service, and which should be susceptible to prompt modification as circumstances dictate. Such international progress in this field can best be attained by full operational-technical discussion and debate, in which operators, technical developers, and administrators alike fully participate. A step in this direction seems to have been taken when the United Maritime Consultative Council, at its second and final session in October of last year, adopted certain recommendations which since have been transmitted formally to the Secretary General of the United Nations. Until the maritime interests have agreed on truly international objectives, world-wide international progress in marine radio may be handicapped by troublesome differences in national and regional facilities, practices, procedures and degree of enforcement.

18. The development and the actual installation of efficient and modern radio apparatus to facilitate navigation and communication obviously does not complete the series of events which will assure the desired advantages to mariners. The equipment must actually be used and used properly, whenever it is appropriate to do so, and it must be kept in good operating condition to encourage its use. We must think and act in terms of preventing distress at sea, in addition to the traditional emphasis on search and rescue measures. The failure of one vessel to determine or make known its position or to report local meteorological data may endanger not only itself but other vessels as well. When ships are endangered, life and property are endangered. Ship radio operators are compelled by existing international regulations to stand a watch for signals of distress which may be transmitted because of failure to use or properly use an available navigation aid. Although the supreme authority of the shipmaster at sea is acknowledged, it may be appropriate that there be some international agreement established to cover the element of mandatory use of radio aids to marine navigation.

19. It is entirely possible that a single defective electron tube, the faulty adjustment or incorrect use of a single position-

finding device or automatic-alarm receiver, or failure to keep emergency batteries properly charged may result in a serious maritime disaster. This leads to the opinion that adequate maintenance and thorough methods of inspection and enforcement of regulations are indispensible if real improvement and effectiveness in marine navigation is to be achieved through the world-wide use of radio. Perhaps more positive international regulation covering inspection and enforcement is needed. With this thought in mind, the various national methods of inspection and enforcement with respect to ship radio installations for safety purposes should, as a progressive measure, be examined and strengthened internationally wherever remedial action is indicated.

20. One of the present ship radio requirements of the Safety at Sea Convention which seems to bear special investigation with a view to possible future modification is contained in Article 47 of Chapter V - entitled "Safety of Navigation." This Article provides that "every passenger ship of 5000 tons gross tonnage and upwards shall be provided with an approved direction-finding apparatus (radio compass)". Note that this applies only to the larger passenger ships. Aside from the radio facilities required for radiotelegraph communication, there are no other radio aids to navigation made mandatory for ships by this Convention. While such modern position-finding devices as loran and radar also are valuable for enhancing safety of navigation at sea, the governing factor at this time which determines whether they will be utilized or not is likely to be the purely economic point of view. Since it is reported in some quarters that these and similar devices will pay for themselves when used on board commercial vessels for a stated period of time, we may expect to see a large number of voluntary installations in the future. Whether or not such voluntarily installed apparatus intended for use in navigation should be subject to government inspection and regulation or should be made compulsory is a pertinent question for future consideration, bearing in mind that government inspection and regulation, when available, is really a form of international insurance.

21. The maritime telecommunications service can evaluate its progress to date in the development and use of radio as an aid to navigation by observation of the progress in this field made by international civil aviation.

22. The modern commercial aircraft navigated on intercontinental and overseas routes is clearly dependent upon radio for its successful operation. International standardization in the use of radio in this service for both navigation and communication is imperative. Transport aircraft are now flying on world-wide routes. Should one system of communications and navigational aids be used in the United States, another in Europe, and still others elsewhere, it could be necessary

for these aircraft to tow a glider to carry all of the telecommunications equipment required for safe worldwide operation. This situation has been appreciated by airmen and has resulted in the formation of the International Civil Aviation Organization, which is to be brought into relationship with the United Nations. The Communications Division of this organization, subject to endorsement by the Council, is prescribing the basic practices and procedures of aviation telecommunications for world-wide use. Its regional meetings have prescribed the detailed practices and procedures as appropriate to the particular regions. In addition, the Special Radio Technical Division of that organization within the past two years has sponsored demonstrations of radio aids to navigation in London, England; Indianapolis, U.S.A.; and Montreal, Canada. Afterwards it considered what aids should be adopted for the benefit of airmen at this time, what aids should be investigated and developed to meet problems contemplated for the future, and recommended action in this regard by member states to prepare for the Atlantic City Telecommunications Conference. The relation with the shipping interests in connection with distress, search and rescue, and the procurement of meteorological data have been studied and correlated with the objectives of aviation. The scope of combined aviation-maritime interest in these affairs has been recorded. The foremost experts of many countries have been active in all of these deliberations.

23. In consequence of such developments, it must be conceded that commercial aviation is well on its way to completing the construction of its necessarily modern international house to accommodate its radio aids to air navigation. On the other hand, it appears that commercial shipping, which has not been impelled by circumstances to build so rapidly, has not yet completed, for comparable purposes, the ground floor of its own modern international house. Nevertheless, the foundation for such a house has been laid in the occurrence of the IMMRAN meeting in the United Kingdom in May, 1946 and by this meeting in the United States. I believe I may state that shipping will find considerable useful material and appropriate plans for building this house if it looks to the International Telecommunications Treaty, the Safety of Life at Sea Convention, and the International Civil Aviation Organization. Perhaps I am too optimistic but it would be a happy event if these two houses could be located on the same street and adjacent to each other, so that their occupants could become good neighbors and have fireside talks about their common interests.

24. In the very near future, the maritime telecommunications services will be confronted by an unusual opportunity and a serious challenge. I refer to the Radio Administrative Conference which will convene on May 15th at Atlantic City. An opportunity will exist to

better organize world-wide maritime frequency allocations predicated on the use of the best available technical facilities, and to modernize the international radio operating regulations governing ship and coast stations and the use of radio aids to navigation. A challenge to the frequency spectrum space desired by the maritime mobile service may be expected from some of the other principal services of world-wide scope. To take full advantage of this opportunity and to assure maximum protection to the radio facilities needed for safety at sea, the telecommunications representatives of the maritime nations should endeavor to overcome at Atlantic City any international differences in order to form a united front and together present a comprehensive and coordinated plan embracing the frequency spectrum space necessary to the reasonable and efficient operation of international marine telecommunications. In other words, the world shipping interests should realize that, as a maritime radio group, all of them are in the same lifeboat.

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INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN · · · APRIL 28-MAY 9, 1947

STANDARDIZATION OF SHIP-SHORE TELEPHONE COMMUNICATIONS AT THE ENTRANCE OF HARBORS

Introduction

1. The radio aids to marine navigation which have been studied until now relate especially to ocean, land-fall, and coastal navigation. The present proposal refers to the entrance of ships in the harbors and their berthing.

2. It appears desirable that, when a ship approaches her port of destination, she should get facilities for exchanging information with the port authorities in order to give notice of the time of berthing, to make known her cargo, to ask which berth is available for her, etc. These communications would greatly be facilitated if, in all the ports of the world and for all ships, they were performed on one, or preferably two, standardized frequencies, as in the case of distress calls. This would simplify the installation on board ships and ashore. A permanent watch would be kept on these frequencies.

3. It is understood that the United Kingdom, at the forthcoming conference at Atlantic City, will propose to allocate a band of 156-166 Mc/s to short range ship-shore communications. IMMRAN Document 7 of the U. S. Delegation at the present meeting, "Frequency Bands and Their Utilization for Marine Radio Aids to Navigation", proposes that the 156.81 Mc/s frequency be reserved for information and instructions to be given to mariners by shore-based radar stations.

Proposal

4. In the same way two frequencies, with a difference of 5 Mc/s (in order to make easier the adoption of a stabilizing device which would be common to the transmitter and receiver on board), could be allocated in this band for such information; the lower one, for

calls from the ship; the higher, for answer from the shore station.

Characteristics of Equipments

5. The power of shore and ship transmitters could be limited in order to avoid interference. Type of modulation (amplitude, frequency, or phase) could be chosen according to an international agreement; in the last two cases the maximum swing (in frequency or phase) should be fixed. Secondary characteristics, such as a code of call signals, could be recommended in order to make continuous watch easier.

Conclusions

6. We therefore propose

(1) that this meeting should issue the following recommendation to be submitted to the Atlantic City Conference: in the band 156-166 Mc/s, two frequencies, separated by 5 Mc/s, should be allocated for the exchange of information between ships and harbor authorities;

(2) that a meeting in the near future should fix the specifications to which the equipment would have to comply.

4. In considering position fixing systems, we have assumed that Decca is a firm marine requirement as a pilotage and coastal aid; and that Consol, although not a firm marine requirement, might be an air requirement and might be of considerable value to the mariner who should ensure that due weight is given to the possibilities of marine use of this system when stations are erected for air purposes.

5. We have not attempted - in fact it would not be possible on a small-scale chart - to show the areas in which pilotage, coastal and ocean aid could be provided. The circles on the chart indicate the areas in which the facilities offered by the systems can reasonably be used to their greatest advantage either by day or by night. It is realised that the accuracy requirements of the mariner cannot be fully met in all parts of the areas shown, e.g. coastal requirements will not be met throughout the Decca circles. For Decca a circle of radius 240 nautical miles from the centre of the chain has been used; this is the range that is accepted by the United Kingdom for the English chain. The area need not of course be circular but may be elliptical if that suits a particular area better. In the case of Consol, a circle of 1000 miles radius from the station has been taken. The probable desired orientation on account of the air interest has also been considered though, of course, close co-ordination between air and sea will in practice be required.

6. The following notes on certain areas help to explain the chart.

a. North Sea, Norwegian Coast, British Isles, English Channel, Biscay and Gibraltar Approach

Although all these areas do not strictly come within the definition of "coastal waters", it is considered that an aid suitable for coastal use is a requirement out to the 100 fathom line. In fact there are so many large sea ports, so many narrow channels, estuaries and submerged dangers that in a large portion of these areas "pilotage" accuracy may be desirable. It is of course appreciated that in the outer approaches coastal accuracy will not in fact be achieved, but a large measure of assistance will be provided.

b. Eastern Seaboard of North America

The arguments under a. above equally apply although areas where pilotage accuracy is desirable are relatively limited. Several Decca chains are shown in the plan, to provide the desired assistance.

c. North Atlantic

Between a. and b. above no fixed dangers exist, but there is a considerable volume of shipping. The ocean passage is adequately covered in the plan by Consol stations in Iceland, Newfoundland, Bermuda, Azores, Spain and Ireland, with possible additions in France and U.S.A.

d. Equatorial Atlantic

This area is mainly an ocean route from North to South and an air route from East to West. It can be partially covered by Consol though two Decca chains in West Africa might be considered desirable.

e. Western South Atlantic

The Plate estuary is a good example of a Decca requirement and to a lesser extent so is Rio de Janeiro. Consol stations at Rio, Natal and Monte Video would provide good coverage over the ocean whilst an additional station on the Falkland Islands would give great assistance in the Horn area. The Magellan Straits seem to call for Decca but a chain has not been included on account of the economic factor. It appears that radar will have to meet requirements in this area.

f. Cape of Good Hope

This area is not beset with shallow water but is a region of fog, strong and variable currents and violent weather conditions. Two Decca chains in the Union, possibly elliptical in shape, would give adequate coverage. Backed up by two Consol stations and a third at Lorenco Marques the Cape storms would lose much of its meance to mariners.

g. Indian Ocean

The economic factor is especially difficult in this large area of diverse routes. We have shewn Decca facilities at Bombay, Calcutta, Singapore, and in Ceylon and the Perim Straits; the remaining areas being largely covered in the plan by Consol.

h. Australia

Cape Leeuwin has a reputation much like that of the Cape of Good Hope and a Decca chain has therefore been sited in its vicinity. Chains at Adelaide, Melbourne and Sydney give complete cover round the south eastern corner. Two Consol stations in Western and two in Eastern Australia give good ocean assistance when approaching the continent.

It would probably be uneconomic to cover the Great Barrier Reef in view of the small amount of shipping operating in that area.

i. Pacific

In this vast ocean area again the economic factors are especially difficult. Only a few of the more important areas have been considered in order to give a general indication of the circles of coverage which might be obtained from Consol and Decca.

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN. · · · APRIL 28-MAY 9, 1947

MACHINERY FOR THE CO-ORDINATION OF AIR AND MARINE RADIO NAVIGATIONAL AIDS

1. The first I.M.R.A.M.N. agreed that "whenever possible and expedient radio aids to navigation should be used in common for civilian aviation and shipping, and that organisational machinery would be required to plan for and achieve this end". In the U.K. a Committee of representatives of air and marine Departments has been set up to consider and co-ordinate problems concerning radio navigational aids which affect both air and marine interests.

2. One of its most important functions is to co-ordinate U.K. air and marine policies on radio aids to navigation prior to international meetings on either the air or the marine side. In this way U.K. delegates to international air or marine meetings will be fully aware of the impact of their policies on U.K. marine or air interests, respectively, and will be able to take this into consideration in their deliberation.

3. The Committee has also considered such problems as the possibility of combined air and marine use of Gee, integration of air and marine M.F. radio beacons, and the provision of charts for use with either air or marine radio navigational aids.

4. The work of the Committee has shewn the importance of the general problem of co-ordination of air and marine interests in the field of radio navigational aids, on both a national and an international basis. Hitherto international discussions by the air or marine sides have not taken full account of the interests of the other, and the need for co-ordination of the activities and policies of the two sides has become increasingly apparent. Co-ordination might be achieved by representatives of air and marine international organisations attending each other's meetings, or by special joint international meetings to co-ordinate the two

sides. An alternative method is to co-ordinate air and marine interests in each country as a domestic matter prior to international meetings on either the air or marine side, so that delegates to any international meeting could speak with both interests in mind. The U.K. is strongly of the opinion that this latter course would be more effective and more economical, and suggests that all countries should approach the problem from this point of view.

5. This U.K. view was presented to P.I.C.A.O. in Montreal in November 1946 in an Address by Mr. W. Carter.

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION

NEW YORK CITY AND NEW LONDON, CONN · · · APRIL 28-MAY 9, 1947

CHARTS FOR POSITION FIXING SYSTEMS

1. Hitherto charts have been drawn to provide the mariner with a basic document on which to plot his position relative to objects within the visible horizon or astronomical position lines (celestial navigation), in addition to plotting the course for his passage. With the evolution of radio navigation it has become necessary for the mariner to position himself relative to beacons hundreds or even thousands of miles beyond the visible horizon.

2. This requirement will introduce problems of an exacting nature in the national and international co-ordination and standardisation of geodetic data (such as plumb line error and figure of the earth) to enable the intrinsic accuracy of radio navigation to be fully utilised over the seas of the world. For example, it has been found that the primary triangulations of neighbouring countries (or even of different parts of the same country) are not always correlated.

3. These problems will probably be discussed at the International Hydrographic Bureau Meeting which is taking place at the present time - April 1947. Meanwhile, it is suggested that the difficulties should be borne in mind when details of charts for individual systems are discussed.

Symbols

4. With the multiplicity of various radio beacons now existing, there is a requirement for national and international agreement on symbols and terminology to be used. A provisional list (by no means exhaustive) was put forward at first IMRAMN. (See vol. II of Report, p. 147)

Consol Charts

5. With the introduction of the Bushmills Consol Station on an operational basis, a number of experimental Consol maps for use

with both Stavanger and Bushmills have been produced for trials. A selected number of these maps have been distributed to ships for the purpose of operational research into the marine use of Consol. These results are set out in detail in the U.K. paper on Consol (S.5.i). It has been suggested that since Consol is primarily an ocean aid permitting time for plotting and interpolation that tables may be a more economical and convenient form of presenting Consol information than special charts. They would enable a Navigator to plot his Consol position line(s) on any navigational chart in use. Special charts might be necessary in landfall areas where a direct interpretation is desirable. This question is still under consideration and trials are continuing.

Decca Charts

6. With the introduction of this system for general marine use up to 240 nautical miles from London the Admiralty have put in hand a chart production programme involving the latticing of some 65 charts around the English Coast, including the Channel and southern North Sea. A list of charts issued up to the 1st April, 1947, with those awaiting completion, is attached as an Appendix. These charts may be obtained from agents for the sale of Admiralty charts in the United Kingdom and details of their publication are given in Admiralty Notice to Mariners. These charts, being intended purely for the interpretation of the Decca system, are not corrected up to date for Notice to Mariners and though normally based upon an existing navigational chart should be considered complementary and not superseding the navigational chart corrected for Notice to Mariners. It is understood that the Danish Government will be producing charts for the Danish chain in a similar manner.

British Admiralty Charts for Decca
Charts completed (1st April, 1947)

No. of Chart	Title or Plan of Chart
325	West Schelde - Ostend to Westkapelle.
1089	Orfordness to Blakeney.
1185	River Thames - Sea reach.
1190	Blakeney to Flamborough head.
1607	North Foreland to the Nore.
1872	Calais to the River Schelde entrance.
1895	Dover Strait.
1975	Kentish Knock and the Naze to the Nore.
2052	The Naze to Orfordness.
2148	Cayeux to Boulogne.
2182A	The North Sea - southern sheet.
3347	Heligoland bight and approaches.
6371	Dungeness to Dunkerque including Dover Strait.

Charts to be completed by end of 1947.		Priority.
1191	Flamborough head to Hartlepool	x
1192	Hartlepool to St. Abbs head	x
1825B	Irish Sea - Sheet 2.	1
1408	Orfordness and Scheveningen to Terschelling zeegat.	2
2322	Scheveningen to Ameland	3
1406	Dover and Calais to Orfordness and Scheveningen.	4
1491	Harwich Harbour.	4a
1179	Bristol Channel.	5
1170B	Great Ormes head to Liverpool.	6
2450	Portland to Owers.	7a
2451	Owers to Dungeness.	7b
2612	Fecamp to Dover.	7c
2613	Cape Levi to Fecamp.	7d
2669	Channel Islands and adjacent coast to France.	7e
2565	Trevose head to Dodman point.	8
2620	Eddystone to Portland.	9
442	Lizard head to Start point.	10
1178	Trevose head to Bull point.	11
1410	St. Govens head to New Quay.	12
1411	New Quay to Holyhead.	13
1170A	Holyhead to Great Ormes head.	14

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
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THE ALLOCATION OF FREQUENCIES FOR RADIO AIDS TO MARINE NAVIGATION

The over-riding consideration in providing Radio Aids to Navigation is to ensure hundred per cent reliability. The standard of reliability required for navigation is higher than that required for communication services, and systems and frequencies have to be chosen with this consideration very much in mind. A system of navigation dependent on radio waves can fail when the radio signals become too weak to give reliable indications or when propagation of the waves is not in accordance with the principles on which the system has been designed. Much will depend upon the accuracy desired. Where a rough determination is sufficient there is a considerable margin available for anomalous propagation before the loss of accuracy is material. Where the accuracy required is very high, both signal strength and uniformity of propagation must be correspondingly high. The coverage provided by a radio system varies greatly with the frequency as well as the power. The choice of frequency for any particular service will be determined by the area and location of coverage which is desired and by the accuracy which must be attained at all times of the day and night, independently of weather conditions. The full requirements are so stringent as to be seldom obtainable, and in general decisions on frequencies are made on a balance of conflicting considerations. The following are the proposals for Radio Aids at present in being or about to be employed:-

1. M.F. BEACONS

This system is intended to provide assistance to ships fitted with their own direction finding equipment. It will not provide a service meeting the requirements laid down for Landfall and Coastal aids, but is capable of approaching these sufficiently nearly to give useful assistance in certain localities. It is agreed that this system shall be improved and extended, since it will be many years before it is superseded in all areas by any more accurate system, even if such is adopted immediately.

(a) The frequency must be sufficiently high to permit radiation from an aerial system of reasonable size and cost.

(b) The frequency must be sufficiently high for a loop direction finder of adequate sensitivity to be provided in a restricted space.

(c) The frequency must be low enough to avoid resonances occurring in the ship's hull and superstructure.

(d) The frequency must be sufficiently low to secure reasonable immunity from sky-wave by day and reasonably long range at night. The existing band of 290 to 320 Kc/s is good, but a somewhat higher frequency is acceptable provided it is not above about 400 Kc/s.

The band of 30 Kc/s at present allocated is overcrowded, but it is believed that it can be made to serve if all technical improvements in the design and planning of the Beacon systems are incorporated; provided of course that the Beacon is intended purely as a secondary aid and is not to be extended to provide the full coastal coverage now considered necessary. If no accurate short and medium range radio position-finding system is provided, a much wider band will be essential. This could only be regarded as a most extravagant use of frequencies.

It is believed that other countries will require this band to be extended to 40 Kc/s. This is perfectly acceptable, indeed, desirable. It is felt that this additional 10 Kc/s should be utilised for the erection of any consol stations intended to replace Marine Radio Beacons. It would then be very desirable for this 10 Kc/s to form a buffer band between the Air and Marine Beacon bands, as Consol Stations are likely to be of use to both interests.

2. MEDIUM FREQUENCY DIRECTION FINDING (SHORE-BASED)

In this Aid a shore D/F network obtains bearings on transmissions from the craft concerned. It is intended to provide some assistance for vessels too small to carry their own direction finder, and also to provide assistance to vessels in an emergency, e.g., if their direction-finder breaks down. Large scale use of this system is discouraged, as it "saturates" with a comparatively small number of users, but it is nevertheless desirable as an emergency provision.

The factors which must be considered in choosing a frequency are:-

(a) The frequency must be high enough for reasonable power to be radiated from the restricted aerial system available aboard ship.

(b) The frequency must be high enough for a direction-finder of reasonable sensitivity to be constructed without excessive expenditure.

(c) The frequency must not be so high that there is a risk of interference by sky-wave in day time, or that the night range is unreasonably curtailed. The frequency 365 to 380 Kc/s at present allocated is satisfactory, but a somewhat higher frequency would be acceptable. It should not exceed 500 Kc/s.

The minimum band required would be 10 Kc/s, but a bandwidth of at least 15 Kc/s would be preferred.

The band can be adjusted over a fair range of frequency but care must be taken not to go outside the range frequencies covered by existing shore equipment.

3. CONSOL

The possible Marine uses of this system are twofold:-

(i) Its principal use will probably be as a long-range aid. There is no intention of allocating special Marine Beacons for this purpose, but Air Beacons would be utilised by ships where suitable coverage was provided. Support would, therefore, presumably be given to Air demands for frequencies, but no independent marine demands are forseen.

(ii) The system might also be utilised as a medium range aid to replace M/F Beacons. There is no intention of applying for a specific allocation for Consol for Marine purposes, but it is considered that where a number of M/F Beacons would be replaced by the erection of one Consol station, it might be accommodated in the M/F Beacon band, assuming that the latter was extended by 10 Kc/s as envisaged under (1) above.

The technical requirements in deciding the frequency to be used are:-

(a) This frequency must be high enough to permit radiation from a reasonably dimensioned aerial system.

(b) The frequency must not be so high that the risk of errors due to sky-wave is unduly increased. This point is of particular importance as the economic use of the system for Marine purposes depends on obtaining the maximum range before the accuracy becomes too low.

The bands which have been proposed (265 to 285 Kc/s and 285 to 355 Kc/s) are considered reasonable, but the lower is probably the better.

It would seem virtually impossible to accommodate Consol Beacons in the existing Marine band without the proposed extensions of 10 Kc/s except perhaps in a few special cases where a number of Beacons were replaced by one Consol Station. Even in this case, however, difficulties would probably be experienced due to the latter, with the increased power necessary to obtain the desired range, causing interference with other Beacons sharing frequencies with those replaced.

This system has been supported, so far, purely by air interests. Perhaps support for the erection of a few Beacons, for combined sea-air use in any extended Marine Beacon band (40 Kc/s) could be used to enlist support for other Marine requirements.

4. DECCA (L/F)

This systems is intended to provide Landfall and Coastal coverage and also to provide Pilotage assistance in certain areas. It is well known that the principal danger to shipping exists in the areas in the immediate vicinity of land, and no existing aid other than DECCA appears to be capable of giving the combination of accuracy and coverage required. In addition to its use for normal navigation, the system has valuable specialised applications to Marine and Harbour survey, in the maintenance of sea marks, and for cable laying.

The principal defect of the system, to date, has been the large measure of ambiguity in its indication. This will be eliminated by the introduction of a system of "Lane Identification", which has been demonstrated to Marine Users and agreed as satisfactory to them. There is reason to hope that this system of "Lane Identification" will also make the system useable by aircraft.

The system is liable to serious errors at night at distances exceeding some 240 nautical miles from the transmitters and it cannot therefore be considered as a long range aid.

The facts to be taken into consideration in selecting frequencies are as follows:-

(a) It is necessary to obtain the maximum possible night coverage and for this purpose the lowest frequencies are the best.

(b) The frequency must not be so low that the cost of construction of the aerial systems is unduly increased. The range 70 to 150 Kc/s has proved most satisfactory. Owing to the special arrangements used in this system, the frequencies for a particular chain must be in the special ratios 5:6:8:9. The second frequency is known as the Master frequency and once it has been selected the others are obtained in terms of it.

It is thus seen that if one frequency is fixed so are all the rest.

Unless sufficient channels are available for the majority of the coastal shipping routes in the world to be covered, shipping cannot fully exploit the advantages given by such a system. It is estimated that initially five sets of four frequencies will be required, the Master frequencies of the five sets being separated one from another by 400 c.p.s., i.e. Master frequencies of

84.2 Kc/s
84.6 "
85.0 "
85.4 "
85.8 "

This suggested system would require the following frequency bands to be allocated to DECCA.

70.08 Kc/s to 71.58 Kc/s
84.1 Kc/s to 85.9 Kc/s
112.1 Kc/s to 114.5 Kc/s
126.15 Kc/s to 128.85 Kc/s

that is to say that the total bandwidth required would be 8.4 Kc/s and this is considered to be the absolute minimum that would be acceptable. The Decca Company estimate that at a later date, with improvement in receiver technique nine sets of frequencies could be used within these bands.

Unfortunately few relaxations are possible if the system is to operate successfully. The English chain is at present operating with a Master frequency of 85.0 Kc/s and any change from this channel, would be unfortunate, because not only has equipment been built for this frequency, but a considerable number of charts have been prepared and these would be rendered useless if the frequency were changed.

It is suggested above that the other frequency channels be distributed symmetrically about the present frequency of the English channel. Whilst this is desirable as it requires the minimum alteration to present equipment, it is not considered to be essential. The Channels should, however, be contiguous and equally spaced in frequency, in order to facilitate the design of the receivers.

The effectiveness of a position-fixing system of this type depends very largely upon the continuity and consistency of the transmission and reception. It has proved impossible for the system to give adequate, or even reasonable, service on a non-interference basis.

A proper international allocation of frequencies is made still more essential by the special relationship of the frequencies of the stations in each group since one frequency cannot be altered to avoid a source of interference without affecting all the others.

5. HIGH FREQUENCY DIRECTION FINDING

There is no Marine requirement for this service as an aid to navigation, but it is appreciated that the network of H/F D/F stations likely to be required for the Air Distress Service might, in certain emergencies, be useful to ships in distress. This would be particularly true in the case of smaller vessels unable to carry M/F transmitters of adequate power.

The frequencies used must be chosen by consideration of the propagation conditions at the particular time of day, year and sunspot cycle, and also the range concerned. If the Air network is to be utilised by the Mariner it is clear that those frequencies specified by Air interests will have to be accepted and thus no special Marine proposals are advanced.

The minimum number of frequencies which may be usefully employed will have to be settled in Air users and this decision must be accepted by the Marine interests.

Here again, it will be necessary for such relaxation of requirements as may be possible to be settled by the Air users and accepted by possible Marine users.

6. CENTIMETRIC RADIO BEACONS

Proposals have been made in the U.K. for a centimetric radio beacon with rotating aerial beam. The beam of energy is modulated as it rotates in such a manner that a ship within the radio horizon can, with simple receiving apparatus, determine the bearing and identity of the beacon.

The factors which determine the frequency to be used for a radio lighthouse of this type are as follows:-

(a) The frequency must be high enough to enable a beam width of less than 10^o to be obtained with an aerial of moderate size capable of rotation at a speed of about 60 r.p.m.

(b) The frequency should be low enough to allow horizon range to be obtained with a simple crystal-video receiver.

(c) The frequency should preferably be in a region where suitable valves and other R/F components have been developed.

The extent of frequency band required for the pulse system at present proposed, is determined by considerations of magnetron stability and ease of manufacture; a band of about 1% is about the minimum acceptable.

A frequency allocation of 50 Mc/s width in the vicinity of 3000 Mc/s would be satisfactory taking the consideration of the second and third paragraphs into account. The proposed frequency band of 3350 to 3400 Mc/s would be satisfactory, but any similar band in this region would be acceptable.

7. SHIPBORNE RADAR

The objects of shipborne radar are as stated in the U. K. specification for a Marine Radar Set:-

(i) To provide navigational assistance in the vicinity of coastlines and islands.

(ii) To provide warning of the proximity of other surface craft and obstructions in a manner which will enable a collision to be avoided.

(iii) To provide an indication of the position of the ship in relation to buoys, shorelines, and navigational marks in a form which will be of assistance to the navigation of restricted waters.

The factors to be considered in choosing frequency bands for marine navigation radar are as follows:-

(a) High azimuthal resolution and good detection range on low coast, buoys and small vessels are important characteristics in radar to be used for navigation in restricted waters.

(b) To obtain the required characteristics in a radar set of moderate power with an aerial capable of being fitted in the majority of merchant ships, the operating frequency should be greater than 5000 Mc/s.

(c) An upper limit to the operating frequency is set by attenuation and scattering in rain, etc., these effects increase rapidly at frequencies in excess of 10,000 Mc/s, and at times in the tropics reduce the efficiency of such equipment as frequencies of 10,000 Mc/s and below.

Such operational experience as is available at present indicates that the advantages of operating at around 10,000 Mc/s outweigh disadvantages due to atmospheric effects in most parts of the world.

An additional frequency band near 5000 Mc/s should be available.

(d) Valves and other R/F components and test equipment have been developed in the U.K. for a comparatively narrow band in the vicinity of 10,000 Mc/s, and some time must elapse before components are freely available in other parts of the sprectrum between 5,000 Mc/s and 10,000 Mc/s.

The width of frequency band required is not determined by consideration of mutual interference, since large numbers of sets of this type can operate on the same frequency without significant prejudice of performance, but by two other factors:

(A) the spread in production of operating frequency of the fixed frequency magnetrons used as transmitting valves.

(B) the bandwidth of other non-adjustable R/F components.

A frequency bandwidth of about 2% represents a reasonable compromise between the conflicting requirements, the minimum acceptable bandwidth being 1%

The proposed frequency allocations of 9320 to 9500 mc/s and 5460 to 5650 mc/s are therefore regarded as satisfactory. U.K. manufacturers have planned production of components for the 9320 to 9500 mc/s band or for the 9400 to 9500 mc/s part of it.

Components for the 5460 to 5650 mc/s band have not been developed in the U.K. Any band of similar width between 5000 mc/s and 6000 mc/s with a minimum extent of about 100 mc/s would be acceptable.

It is understood that the U.S. have a requirement for a frequency allocation 3000 to 3240 mc/s. No requirement is foreseen for a frequency allocation in this part of the spectrum for U.K. civil marine radar.

8. RADAR BEACONS (RACONS).

Radar beacons for civil marine radar may be used to enable a ship fitted with radar to fix its position with certainty in waters where the plan display of the coast line is not sufficiently characteristic for unambiguous identification, or at ranges in excess of normal radar range in the vicinity of low lying coast or for making a land-fall.

A number of types of centimetric radar beacons, which use the transmission of narrow band of frequencies adjacent to a radar frequency band, have been developed and installed for air/marine use in the U.S. There has been no development or production of a beacon of this type in the U.K, but it is clearly important that the frequency bands to be used for them should be internationally agreed, and the proposed bands of 3246, to 3266 mc/s 5440 to 5460 mc/s and 9300 to 9320 mc/s are satisfactory.

The width of the band 9300 to 9320 mc/s, which is the only band of interest to the U.K. at present, represents the minimum acceptable with existing techniques of frequency stabilisation and measurement.

9. RADIO TELEPHONY FOR USE WITH SHORE BASED RADAR.

The purpose of providing V.H./F.R./T communications for use with harbour supervision radar is to enable the authority controlling the shore radar to pass information and directions to ships within horizon range, to receive reports from such ships, and to determine identity by D/F on ship transmissions in a manner which facilitates correlating with the radar display.

Any frequency above 100 mc/s would be technically suitable, the region below 200 mc/s would be particularly convenient because:-

(i) techniques are fully developed, and inexpensive valve types and be used.

(ii) A cathode ray direction finding technique has been developed for use in the 100 to 150 mc/s band.

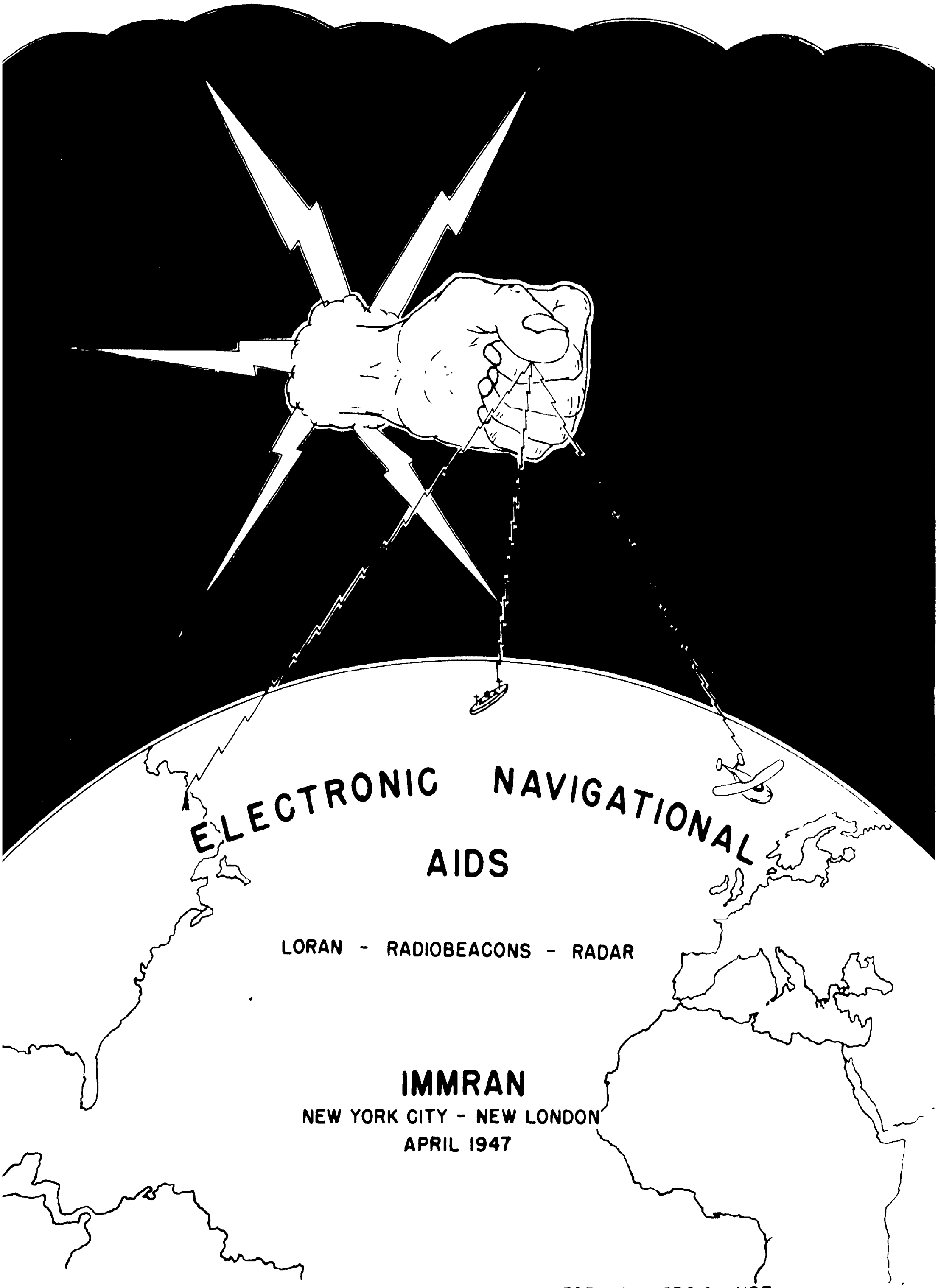
Channels are essential for

(a) transmission from the shore radar site

(b) transmission from ships

The provision of two other channels would be desirable for the purpose of identification by measurement of bearing and range.

The width of channel is determined by economical limits to which frequency can be held in this region with simple apparatus. 100 kc/s could be regarded as a reasonable width. The proposed allocation of one channel near 150 kc/s is acceptable, but may be found inadequate under dense traffic conditions. Two channels 100 kc/s each are considered to be desirable.



ELECTRONIC NAVIGATIONAL AIDS

LORAN - RADIOBEACONS - RADAR

IMMRAN
NEW YORK CITY - NEW LONDON
APRIL 1947

A BASIC DESCRIPTION OF ELECTRONIC AIDS AS APPLIED FOR COMMERCIAL USE

FOREWORD

United States Coast Guard Headquarters
Washington, D.C.

This pamphlet on loran, radiobeacons, and radar is published for the information of the United States maritime industry and United States commercial air lines interested in the application of electronic navigational aids. It should be of benefit to the industries concerned in improving the safety, economy, and efficiency of transportation over the areas of the world.

The information has been prepared largely to answer many inquiries received by the United States Coast Guard on these subjects. The Coast Guard operates an extensive system of loran and radiobeacon stations for the protection of overseas transportation and has promulgated suggested specifications for radar equipment.

Operational tests relating to electronic navigational aids for use by navigators is undertaken by the Coast Guard as a normal function since its duties include the saving of life and property at sea, maintaining and operating aids to navigation, and merchant marine inspection.

It is believed that this non-technical treatment of the subjects presents sufficient facts for an evaluation to be made in determining the benefits to be derived in applying these equipments to the safeguarding of life and property at sea.

Joseph F. Farley

JOSEPH F. FARLEY, Admiral, USCG,
Commandant.

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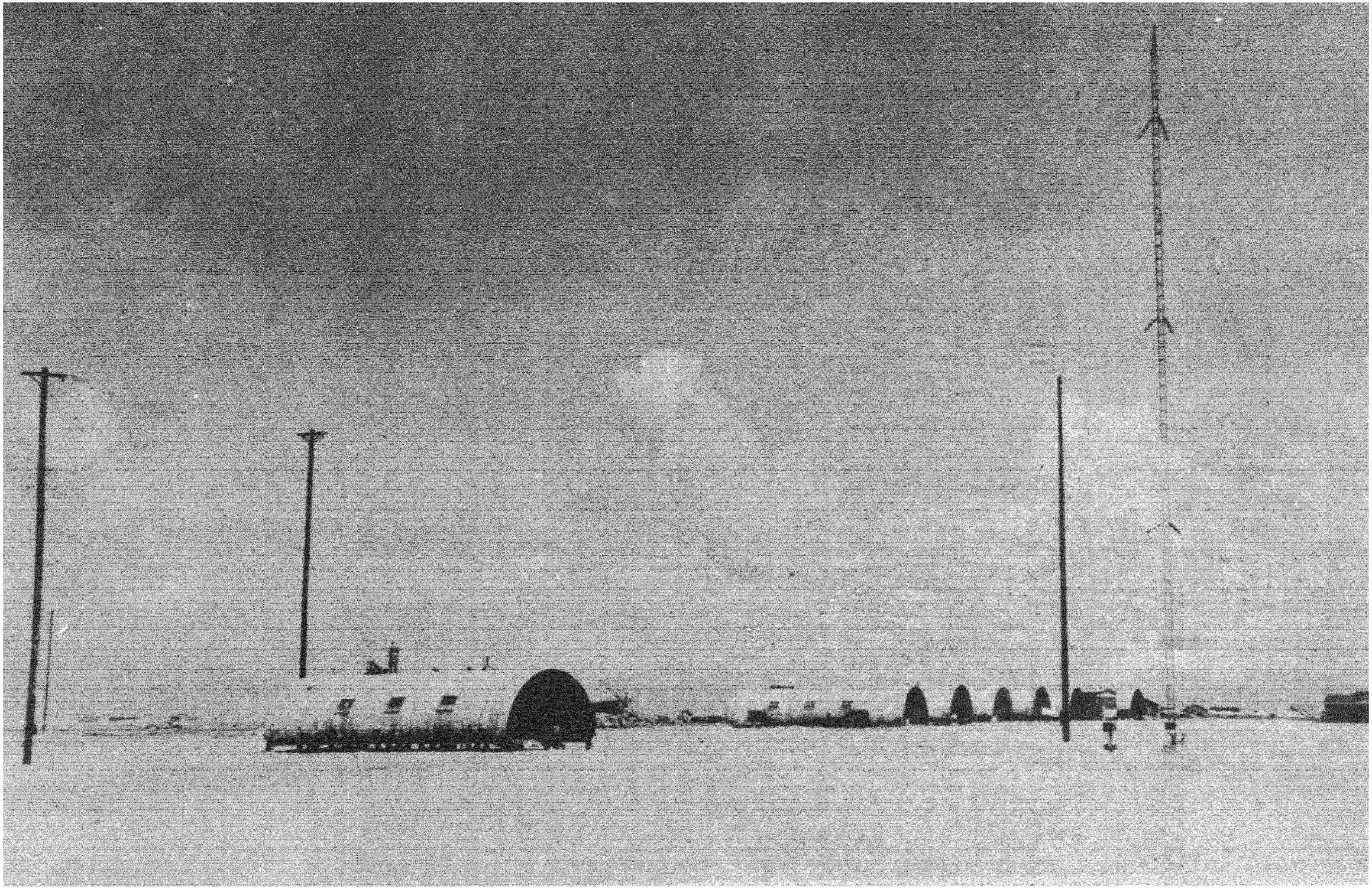


FIGURE 1-1 — A typical Loran transmitting station of the United States Coast Guard.

CHAPTER ONE

LORAN SYSTEM

INTRODUCTION

The Loran system is a modern electronic aid to navigation by means of which navigators on or over the ocean can determine their position accurately and quickly, day or night, and under practically any condition of weather and sea. The name "Loran" was derived from the words "LOng RAnge Navigation," which describe in general terms the system's relative utility when compared to ranges of other electronic navigational aids. The effective range of Loran is as great as 1,400 nautical miles at night and 750 miles during the day (Fig. 1-2). The accuracy obtained is comparable to that which may normally be expected from good celestial observations. Even though such precision is attained, the determination of position by Loran requires but 2 to 3 minutes time.

The navigator can think of Loran as merely a new method of determining lines-of-position. These loran lines can be crossed with other loran lines, with sun lines, star lines, soundings, radar range circles, or bearings, to provide fixes. Loran lines are fixed with respect to the earths surface; their determination is not dependent upon the ship's compass, chronometer, or other mechanical or electronic devices. Loran shipboard equipment requires no special calibration and is not affected by the arrangement or disarrangement of shipboard antennas, cargo booms, ventilators, etc., as in the case of radio direction finders.

Loran signals are on the air and available to navigators for 24 hours per day, and cover the major shipping lanes of the seas and oceans of the world. Developed as a wartime necessity, the system is now at the disposal of private shipping --- any nation, any line, all may make free use of it.

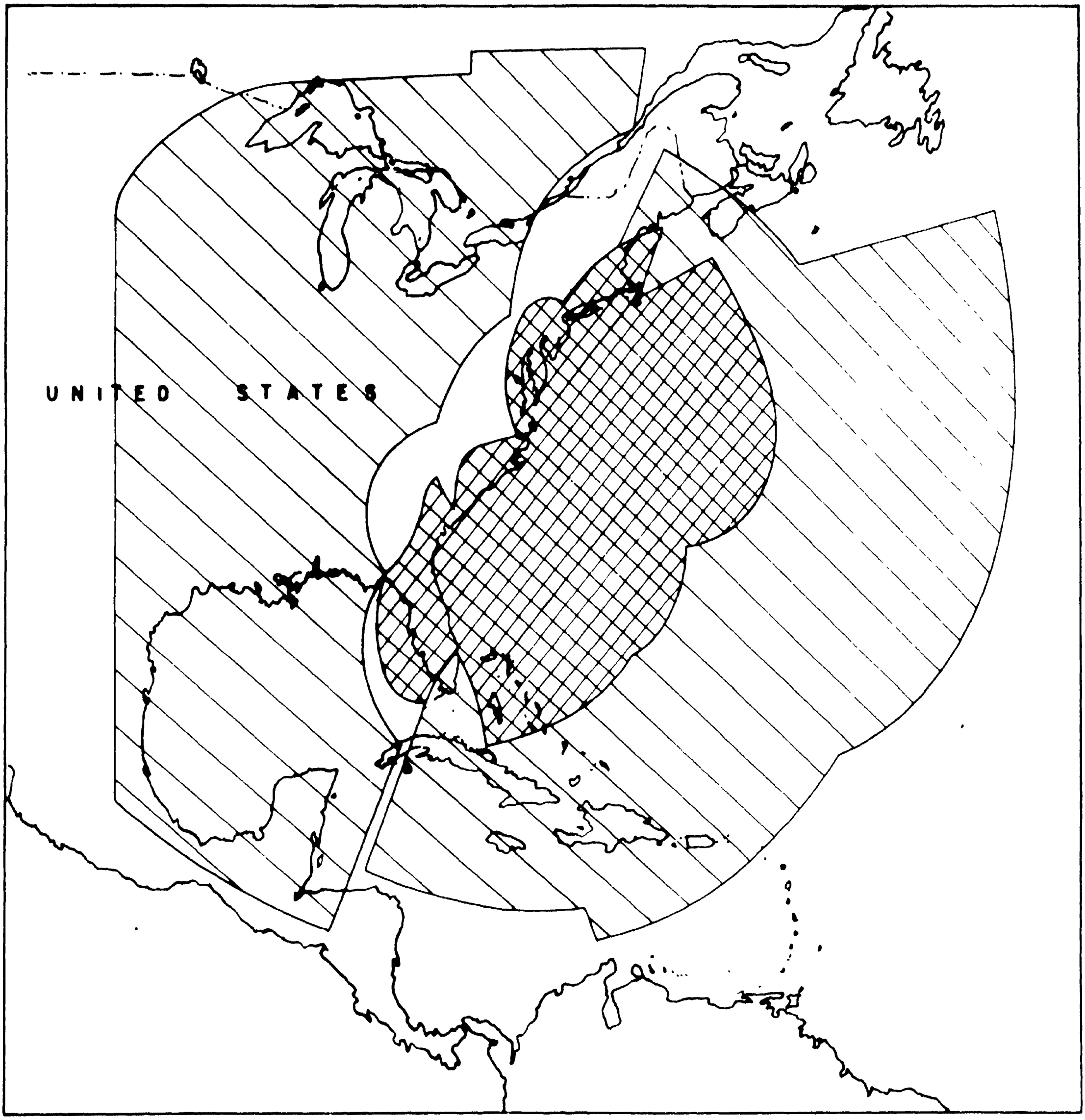


FIGURE 1-2. TYPICAL DAY AND NIGHT LORAN COVERAGE AREA.

DAY & NIGHT COVERAGE AREA.

NIGHT COVERAGE AREA.

PRINCIPLES OF OPERATION

Loran operates on the following principles:

1. Radio signals consisting of short pulses are broadcast from a pair of shore-based transmitting stations.

2. These signals are received aboard the ship or plane on a special loran radio receiver.

3. The difference in times of arrival of the signals from the two radio stations is measured on a special loran indicator.

4. This measured time-difference is utilized to determine directly from special tables or charts a line-of-position on the earth's surface.

5. Two lines-of-position, determined from two pairs of transmitting stations, are crossed to obtain a loran fix.

Since radio signals travel at a constant speed, the direct relationship between time of travel and distance traveled exists. Thus, measurement of intervals of time is, in essence, a measurement of distance itself.

The radio signals which are transmitted by loran stations are not continuous transmissions such as those of everyday commercial broadcasting stations, but are "pulse" signals, or short bursts of radio energy transmitted at regular intervals. The use of "pulse" signals permits the individual signals to be identified in order that time measurements can be made. This would not be possible if the transmissions were continuous.

Because the basic loran measurement evaluates the difference in the distances between the navigator and each of two fixed transmitting stations and not the individual distances themselves, there are many points at which the difference would be the same even though the distances varied widely. These points fall along a smooth curve (hyperbola) which is known as a loran line of position. Therefore, when a navigator has obtained a loran reading from a pair of transmitting stations he has determined that his true position lies at some point on a particular loran line of position. By making loran measurements on a second pair of stations a second line of position has been identified and the

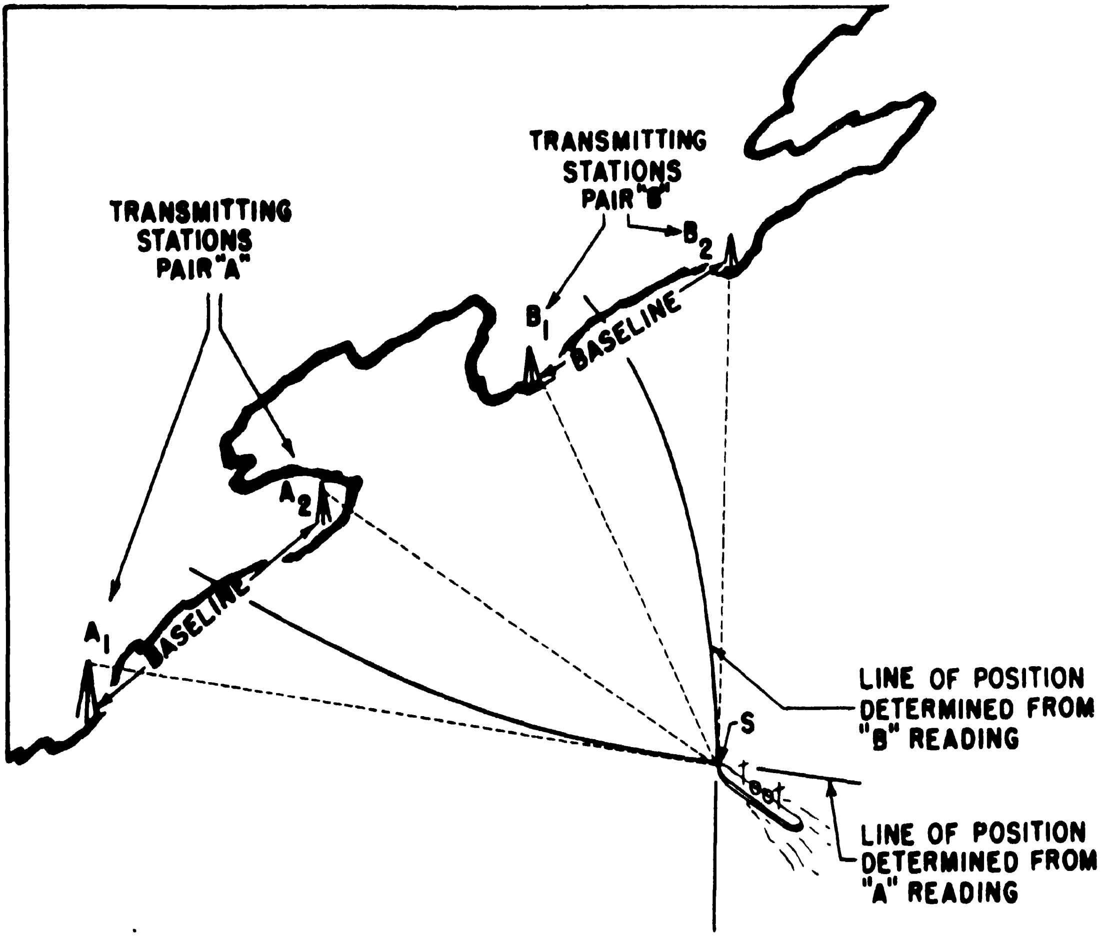


FIGURE 1-3

Navigator aboard loran-equipped ship at "S" establishes "fix" by determining two lines of position, "A" and "B" by loran measurements.

Line of position "A" is found by measuring the time difference between signals received from transmitting stations A_1 and A_2.

Line of position "B" is found by measuring the time difference between signals received from transmitting stations B_1 and B_2.

The navigators fix is established at the point of intersection of the two lines of position.

The latitude and longitude of the navigator's position is determined from the loran data by using either the loran charts or loran tables.

navigator's true position or "fix" has been established at the point of intersection of the two lines.

In order to simplify the navigator's problem of interpreting the loran data in terms of coordinates of latitude and longitude, loran charts are provided which picture the electronic lines of position with respect to some convenient map of the region in which the ship is sailing. The same information is available in the form of loran tables for the convenience of navigators who desire to cross loran lines of position with celestial observations on their regular navigators chart.

The diagram of figure 1-3 illustrates the basic principles of the determination of position by means of Loran.

TRANSMITTING STATION FUNCTIONS

Loran, through the medium of radio waves, covers the main traffic lanes of the seas and oceans of the globe with electronic lines of position to aid and protect the modern navigator in his pursuit of the ancient art of celestial navigation. These electronic lines stem from the loran transmitting station (Fig. 1-4), the heart of the system.

Because Loran is concerned with the measurement of radio signals from two different sources, loran stations operate in pairs. The function of each station of a loran pair is somewhat different from that of its companion station and each is given a designation which is descriptive of the role which it performs, namely, "master" station and "slave" station.

The "master" starts the cycle of transmission by sending out a pulse of radio energy which is radiated in all directions including that of both the navigator and the "slave" station. After traveling over the distance between the two transmitting stations, which is known as the "baseline," the pulse transmitted by the "master" arrives at the "slave". This signal is received by means of the loran equipment of the "slave" station and the time of its arrival is used by the "slave" as a reference for the transmission of its own signal.

After the "slave" transmits its pulse, the entire cycle is repeated again and again.

Thus the "master" station "sets the pace" and the "slave", by following, completes the loran transmitting cycle. This is shown diagrammatically in figure 1-5.

FIGURE 1-4.— Aerial photograph of a typical loran transmitting station.

By this simple process, a pair of loran stations send out their guiding signals to the hundreds or thousands of navigators who may be within the area of their service which, in most cases, is well over 1 million square miles!

CONTROL OF LORAN TRANSMISSIONS

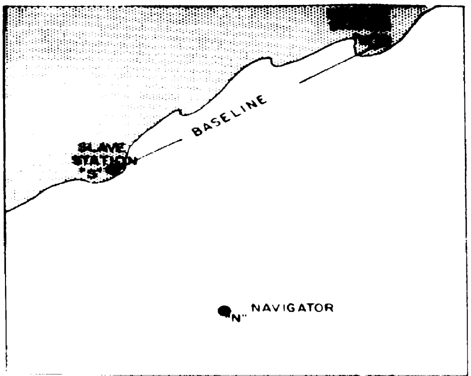
Since the value of the loran system is equal only to the accuracy of timing of the signals transmitted, every precaution is taken to safeguard the functioning of the system. This is effective to such an extent that the navigator may feel certain that the loran data which he obtains is correct. This fact has been proven by the acid test of completely successful loran operation under the severe conditions imposed by the war.

The nature of loran transmitting station equipment makes it necessary for the loran transmitting station operator to observe the signals of both stations continuously during transmission. As a consequence, the man on watch at either station of a pair is in a position to "double check" for the existence of any fault that might occur in the signal of either station.

As an additional precaution to insure proper transmissions, independent "monitor" stations have been established at strategically located points with respect to the transmitting stations. The monitor stations maintain a continuous watch over the accuracy of the loran signals transmitted, assuring that the signals are synchronized within established limits of accuracy and take appropriate action in the case of any discrepancy.

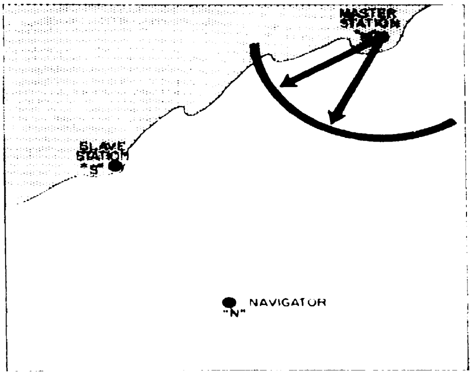
Loran transmissions can be momentarily at fault due to many possible causes such as electrical failure of a part of the equipment or operating error in manipulating controls. Even though these troubles may be minor and of relatively short duration, it is absolutely essential that the navigator be acquainted with the failure instantly and positively. In order to do this, a blinker device is switched in at either of the two stations. "Blinking" produces a characteristic movement of the transmitted signals, which is easily recognizable and serves to warn the navigator that the signals are not to be used for navigational purposes until the "blinking" ceases.

In case the failure is sufficiently serious to prevent transmission entirely, from one of the paired stations, it would not be possible for the navigator to misinterpret the loran signals since the presence of only one of the expected signals



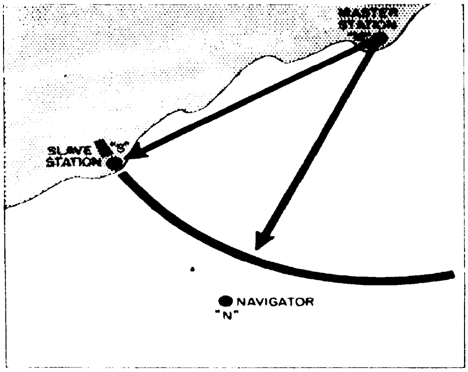
STEP I

NAVIGATOR ABOARD SHIP AT "N" IS WITHIN RANGE OF STATIONS "M" AND "S" AND IS ABOUT TO RECEIVE LORAN SIGNALS



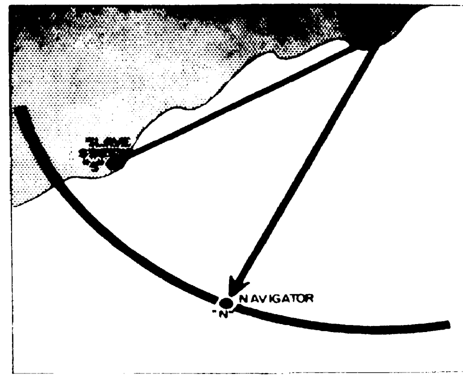
STEP II

LORAN TRANSMISSION CYCLE IS BEGUN BY "MASTER" STATION. PULSE IS RADIATED IN ALL DIRECTIONS AND TRAVELS TOWARD BOTH "SLAVE" STATION AND NAVIGATOR



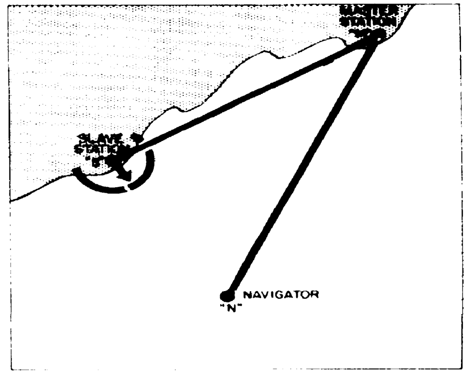
STEP III

PULSE TRANSMITTED BY "MASTER" STATION ARRIVES AT "SLAVE" BUT HAS NOT YET REACHED THE NAVIGATOR



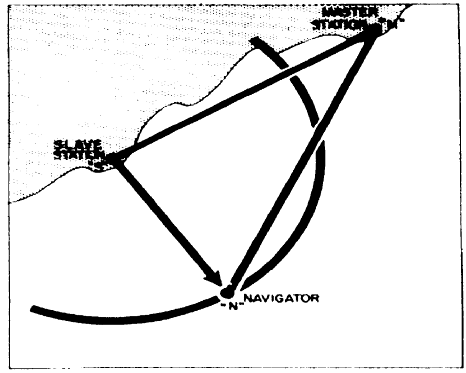
STEP IV

PULSE FROM "MASTER" STATION ARRIVES AT POSITION OF NAVIGATOR. "SLAVE" STATION HAS ALREADY RECEIVED "MASTER" PULSE AND IS WAITING FOR PROPER AMOUNT OF TIME TO ELAPSE BEFORE TRANSMITTING TO ASSURE CORRECT SYNCHRONIZATION WITH "MASTER".



STEP V

AFTER WAITING FOR THE PROPER AMOUNT OF TIME TO ASSURE CORRECT SYNCHRONIZATION, THE "SLAVE" TRANSMITS ITS PULSE. THE NAVIGATOR HAS ALREADY RECEIVED THE PULSE FROM THE "MASTER" STATION



STEP VI

"SLAVE" PULSE ARRIVES AT NAVIGATORS POSITION. SINCE NAVIGATOR HAS ALREADY RECEIVED THE SIGNAL FROM THE "MASTER" STATION, LORAN READING IS TAKEN BY MEASURING THE TIME ELAPSED BETWEEN THE ARRIVAL OF THE MASTER AND SLAVE PULSES. AFTER BOTH SIGNALS HAVE TRAVELLED THROUGHOUT THEIR EFFECTIVE RANGE, THE CYCLE IS REPEATED

FIGURE I-5

SEQUENCE OF OPERATION OF LORAN TRANSMITTING STATIONS

784078 O—48——31

on the air would preclude making any time difference measurements at all from that particular pair. Other pairs would not be effected.

Because of the fundamental checks which are vigilantly maintained on the operating loran signals, the navigator at sea or in the air is assured that any transmissions which he receives, with the exception of "blinking" signals, are accurate, reliable electrical guideposts marking the electronic lines of positions of this modern long-range navigational aid.

TRANSMITTING STATION EQUIPMENT

In order to send out a succession of reliable loran signals to aid navigators at sea in determining their position, the transmitting station has two fundamental responsibilities. The first of these is the generation of radio impulses of the proper frequency, power, and duration. The second is the timing of these radio impulses at the correct intervals and with the required degree of precision. The two major units of transmitting station equipment fulfill these responsibilities, as their names indicate, since they are the loran transmitter and the loran timer.

The loran transmitter is a "pulse" type of equipment of a special design developed specifically for loran application. The radio frequency pulses which are generated by the equipment contain a great deal of electrical energy and are as powerful, although of short duration, as the largest commercial broadcasting stations' transmissions. The loran transmitter functions in such a manner that a single pulse of radio energy is sent out each time the transmitter receives an electrical timing impulse. The timing impulse is known as a "trigger" pulse and serves to "turn on" the transmitter for the duration of the pulse.

The loran timer is the fundamental unit of equipment on which the accuracy of the loran system depends. The timer is made up of the following basic components which serve the purposes indicated:

(a) Radio receiver. -- The receiver permits the reception of loran signals from the distant station and also those transmitted by the local station.

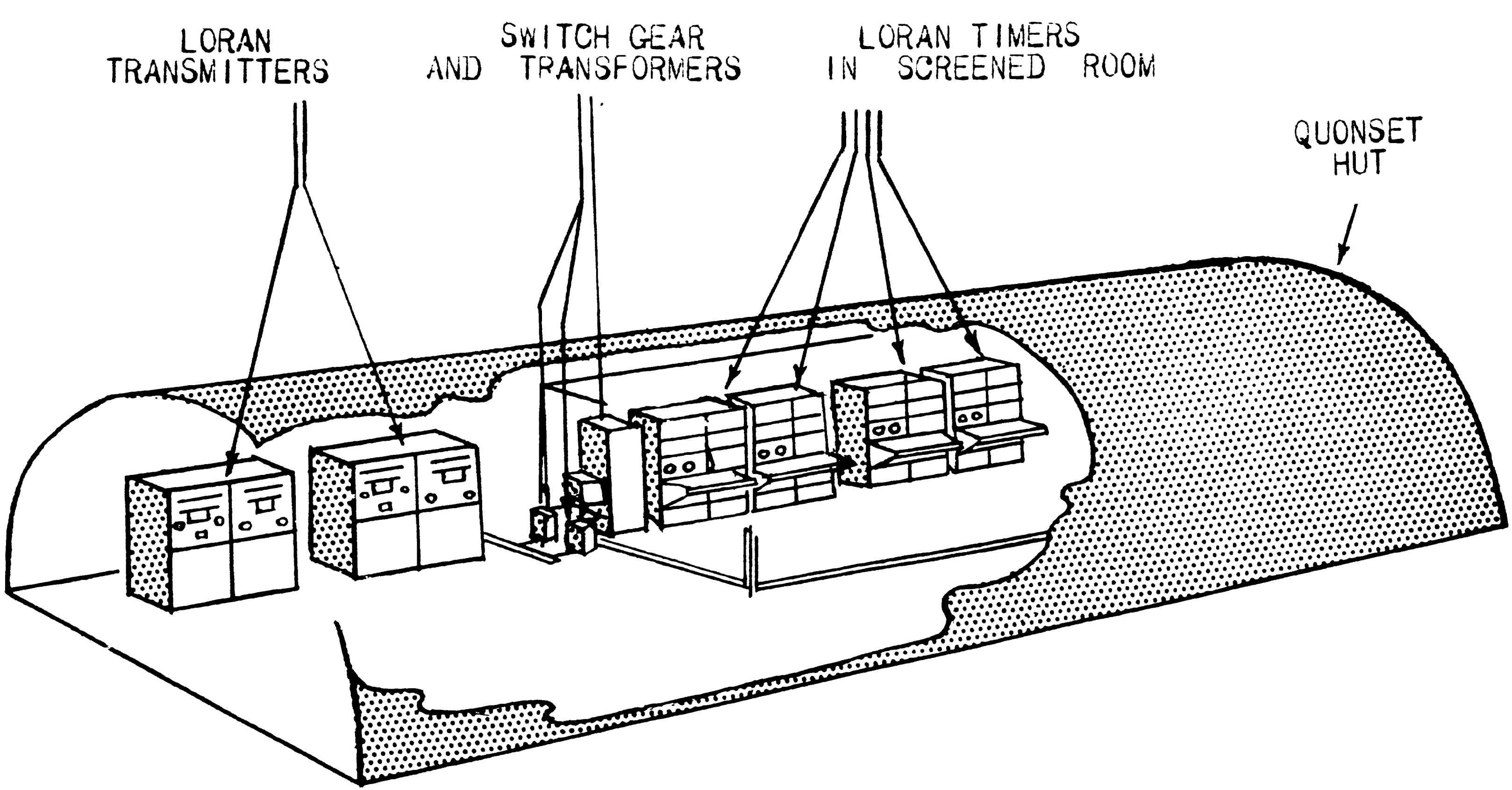


FIGURE I-6

CUT-AWAY VIEW OF QUONSET HUT SHOWING INTERIOR ARRANGEMENT OF TRANSMITTING STATION EQUIPMENT

(b) Indicator. -- Based upon the function of the cathode ray tube which permits the operator to "see" electrical impulses, the indicator permits visual inspection of the signals themselves and other basic functions of the equipment.

(c) Oscillator and timing circuits. -- The complex and precise timing functions stem from a crystal controlled oscillator of the highest laboratory standards. The timing circuits permit the measurement of the time interval between the signals received and furnish the necessary "trigger" pulses for operating the loran transmitter and similar timing pulses for other secondary station functions.

Some idea of the high degree of precision of the loran timer equipments may be illustrated by the fact that a pocket watch of comparable accuracy would run for a period of over 9½ years before it would lose or gain a single second of time.

A third item of equipment which is of fundamental importance in a transmitting station is the loran switchgear. This is constructed as a separate physical unit and contains the necessary switching to permit the operator to place different units of the station equipment in use by properly connecting them to the other units. The switchgear chassis also houses the "attenuator" unit, an electronic switch which effectively disconnects the receiver unit each time the local transmitter sends out a signal. It is necessary to do this to prevent the receiver from being damaged by the strong signal that is generated in the vicinity of the station's own transmitting antenna. During the interval when the local transmitter is not sending out a signal, the "attenuator" effectively reconnects the receiver to permit the operator to receive the signal from the distant station.

In order to provide reliable loran service even in the case of minor failures of equipment it is the established practice in designing loran stations to provide duplicate units of all of the major items. In this manner an equipment failure causes only a momentary pause in the service, since the stand-by equipment can usually be placed in service in less than a minute's time.

Figures 1-6, 1-7 and 1-8 illustrate transmitting station equipment.

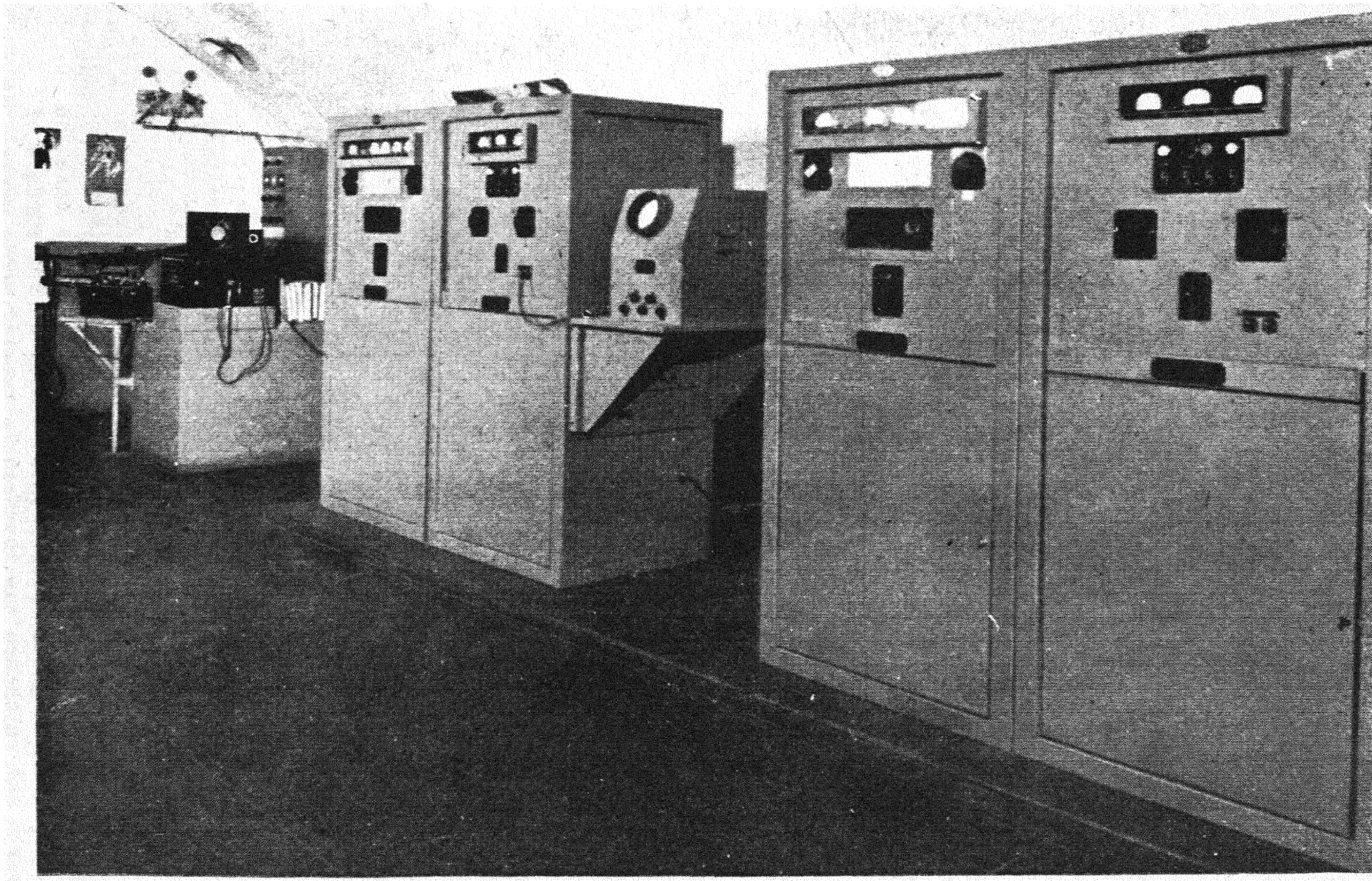


Figure 1-7. — Interior views showing loran transmitters.

EQUIPMENT USED BY THE NAVIGATOR

Loran equipment used by the navigator on shipboard or aircraft at sea in the determination of his position, is known as a receiver-indicator. The receiver performs the functions of an ordinary radio receiver but delivers its output to a visual indicator rather than to a loudspeaker and is designed for the reception of pulsed signals rather than ordinary radio signals. The indicator is essentially an "electronic stop-watch" capable of measuring, in microseconds, the difference in times of arrival of the pulse signals from the two stations of a pair. In the indicator, horizontal traces or lines of light on the screen of a cathode ray oscilloscope form the equivalent of the dial of a watch. A vibrating quartz crystal is the balance wheel, and electrical circuits known as "dividers" or "counters" take the place of gear wheels.

Installation of the receiving equipment is quite simple and can be performed in a few hours time. Actually, installation merely requires simple mechanical mounting of the equipment to the deck or bulkhead, erection of an ordinary radio receiving type vertical antenna, and plugging in the power cord to the local electrical power source.

OPERATING RANGE AND ACCURACY

Three fundamental characteristics of Loran are of particular importance to navigators using the system. These qualities are the following:

(1) Practicability of loran operation over longer distances than is possible with older types of radio navigational aids.

(2) High order of positional accuracy attained.

(3) Reliability of Loran under all kinds of weather conditions.

Vessels and aircraft at sea may determine their position by means of Loran both day and night when they are within 750 nautical miles of the transmitting stations. This is based on the reception of "ground waves" which travel on the surface of the earth and which are the most stable type of radio waves. At night, however, "sky waves" are received which are radio waves

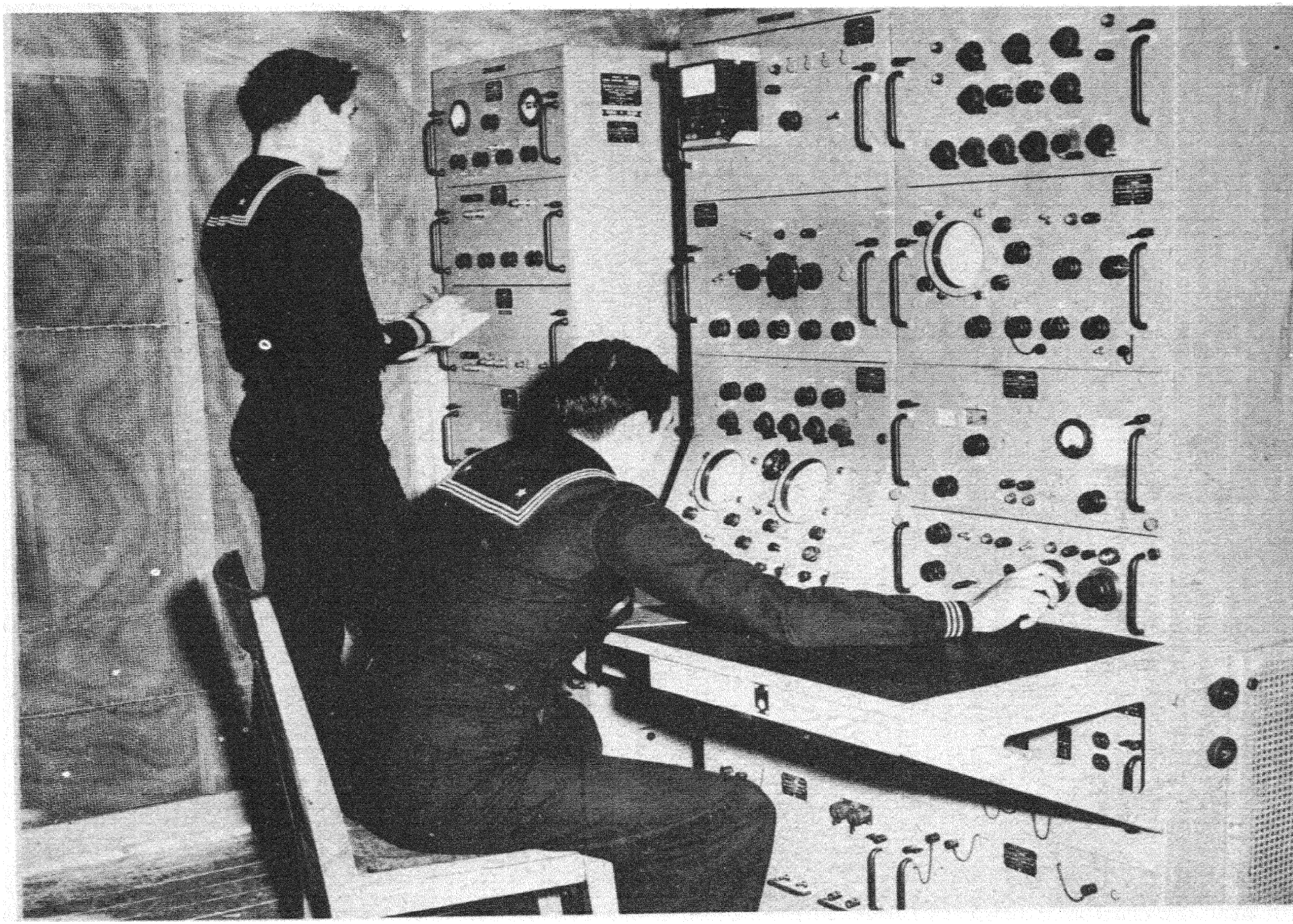


FIGURE 1-8.—Loran station—men on watch at the timing equipment.

that travel outward from the transmitter until they "bounce" or are reflected from a region of the upper atmosphere known as the "ionosphere" and reach the navigator after reflection (fig. 1-11). The use of "sky Waves" extends the range of loran service at night up to a distance of 1,400 nautical miles from the transmitting stations. However, the positional data obtained by using "sky wave" loran signals is somewhat less accurate than the information determined through the use of "ground waves," but is, nevertheless, still at high order.

One of the surprising facts about Loran is that in a matter of 2 to 3 minutes time, a navigator at sea can determine his position with an accuracy comparable to that obtained from good celestial observations which require considerably longer to make and which entail somewhat laborious mathematical computations to interpret.

The accuracy of loran fixes varies considerably, depending on the relative position of the navigator and the transmitting stations, the angle at which the loran lines of position intersect and several other factors. A very rough rule of thumb has been stated to be that a loran line of position has an accuracy of better than 1 percent of the distance of the navigator from the stations; thus a navigator 1,000 miles away from the stations would expect the line of position to be well within 10 miles of the proper position. As the stations are approached, the accuracy increases greatly, and along the imaginary line between the two stations, or "base line," a line of position may have an accuracy of the order of several hundred feet. This feature has particular practical value since the physical arrangement of loran stations is such that a navigator making a landfall will usually approach the shore in this highly accurate area of loran service. Figure 1-12 shows the pattern that a family of loran lines of position make with respect to their transmitting stations and points out the regions of accuracy. Figure 1-13 shows a vessel approaching a harbor along a line of position.

Another important feature of Loran to the navigator is the reliability of the signals and the consequent removal of doubt in the navigator's mind as to the dependability of loran fixes. Loran signals can be received under all ordinary conditions of storms, gales, and other severe weather. This is possible because the ordinary electrical interferences that accompany these conditions obscure the loran signal for only a few seconds at a time and the navigator need only wait for a few moments to obtain usable data. The greatest safeguard in this respect is the fact that loran signals are always accurate when they are received at all. In the case of some unusual interference that might completely block the loran signals, no data could be obtained at all. There is no "in between" condition in the use of Loran for navigation and as a consequence, the navigator may always feel assured that any loran data that he obtains will be of customary accuracy and

Fig. 1-9 Navigator aboard ship obtaining positional data from a "direct reading" type loran reciever-indicator.

Figure 1-10. Navigator aboard ship obtaining positional data from a compact, light weight type loran receiver-indicator.

dependability. For these reasons Loran is an especially valuable asset to navigation during bad weather.

At the present writing, several other electronic aids to navigation have been proposed, but they are in fact hardly beyond the developmental stage. Loran seems to be the best of the long range systems actually proven by use, particularly on the basis of range, accuracy, and low susceptibility to the effects of noise and interference. It is the only one which has been installed on an international, world-wide scale, and represents the greatest number of installations to date. Further, it offers just as many possibilities of future exploitation by simplification, greater range and similar improvements as the other systems claim for future possibility. Latest type loran receiving equipments are designed to provide direct numerical readings, thus simplifying the operation to considerable extent and further reducing the time required to obtain a "fix". The equipments are ruggedly built, circuits are stable, and operation for extremely long periods of time without repair is regularly being obtained. All of the other proposed long distance systems make use of ordinary radio waves and thus are subject to night effect errors, precipitation static and interference. Pulse systems, of which Loran is the most prominent, have outstanding inherent freedom from these serious limitations and otherwise appear capable of duplicating practically all other claimed advantages of non-pulsed systems.

EQUIPMENT AVAILABILITY

Two manufacturers of electronic and navigation equipment have loran receiving equipments in regular production, available for immediate installation. Additional manufacturers are contemplating entering the loran field shortly.

Due to the fluctuating state of the market, delivery prices of the equipment is subject to some variation. However, the equipment can be divided into four general categories, as follows:

Category	Manufacturer	Approximate Cost
Various, War Surplus		Surplus Prices
Compact, light weight		Comparable to medium priced marine D/F
Large Console		Comparable to Console D/F
*Automatic		Unknown

*Under development

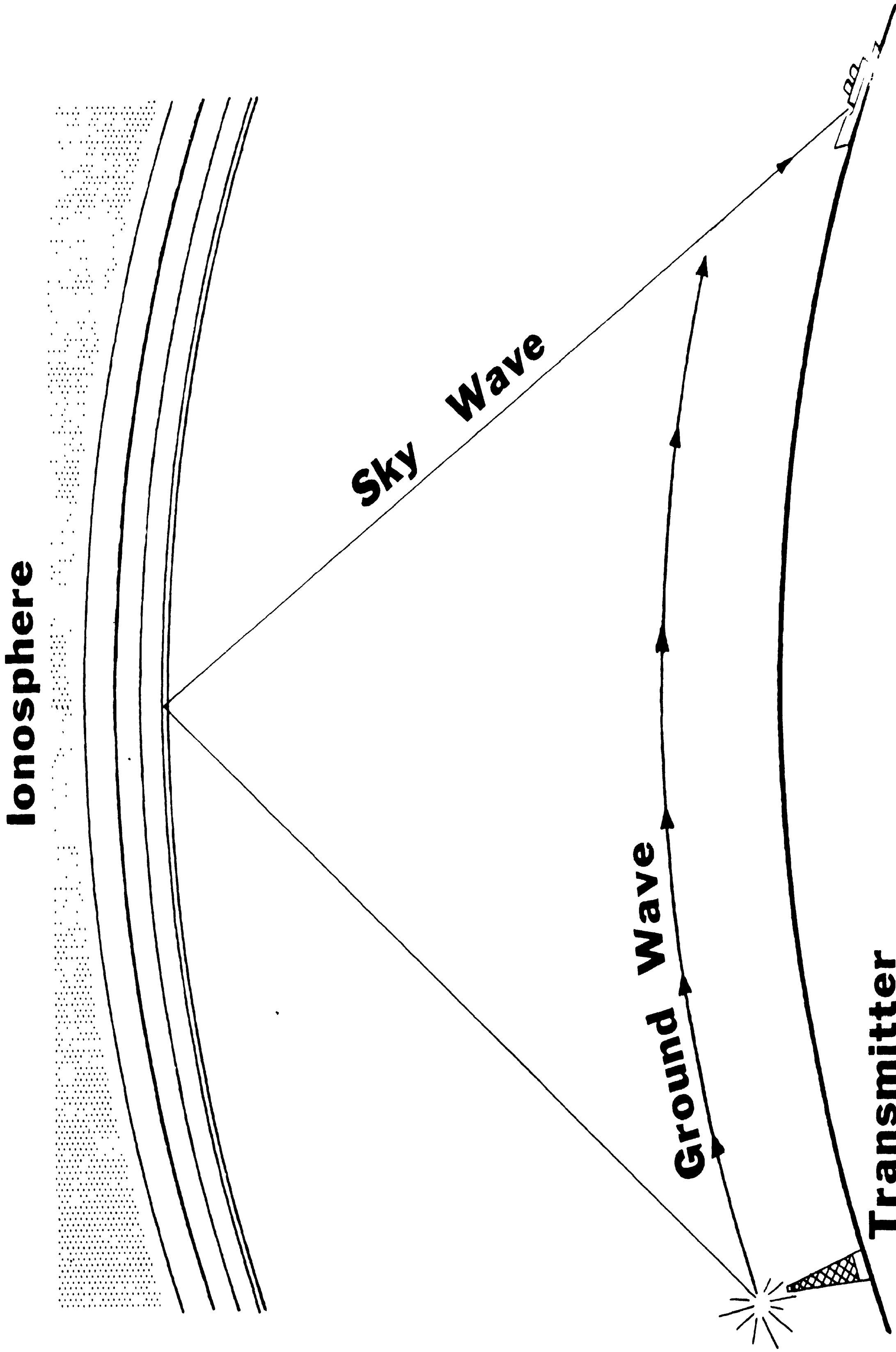


FIGURE I-11

Actual cost figures will be considered small with relation to the safety at sea which Loran affords.

Some manufacturers of the equipment have regular established schools for training navigators in the use of the loran equipment. Since the training period is so short, convenient arrangements to receive instruction during in-port periods of the vessel may be made, as a general rule.

The installation of loran equipment on private shipping vessels is going forward rapidly. Some of the well-known vessels which are now loran equipped include the United States line AMERICA, the Cunard White Star Liners QUEEN MARY and QUEEN ELIZABETH, The Swedish-American liners GRIPSHOLM and DROTTNINGHOLM, and the Matson Steamship Company liner MATSONIA. Some other well-known lines operating loran equipped vessels are: Moore-McCormack, Waterman, Panama Railroad Line, Atlantic Refining Company and the Standard Oil Company of California.

Transoceanic airlines using loran are: American Overseas Airlines, B.O.A.C. (Atlantic Division), K.L.M. Royal Dutch Airlines, Pan American World Airways and Trans Canada Airlines.

The presentation of the loran story should not be interpreted in the light that the new system is the answer to all problems or that the fundamental job of navigating ships and aircraft is going to be radically changed in the immediate future. Loran is unquestionably an important addition to the "tried and true" methods of navigation. Seafaring men should not be tempted to abandon the reliable techniques which they have practiced in the past. Instead, the newer principles should be utilized to supplement the older methods for protection in case of failure of equipment, for sailing in waters where Loran is not available and for numerous reasons probably best known to navigators themselves.

The adoption of Loran is not a difficult thing to accomplish. Its use does not require the services of additional or specialized personnel and navigators may be trained in loran technique in as little time as a single day, certainly in a few days. Implementation of the technique should be undertaken with care to assure that no accident is caused by overconfidence in the system before its limitations have been fully appreciated.

SUMMARY OF VALUABLE FEATURES OF THE LORAN SYSTEM

The features which make Loran a valuable tool and a highly regarded supplement to the art of navigation are inherent in the technology of the system itself. It is a radio device which makes use of the speed of travel of radio signals as its fundamental

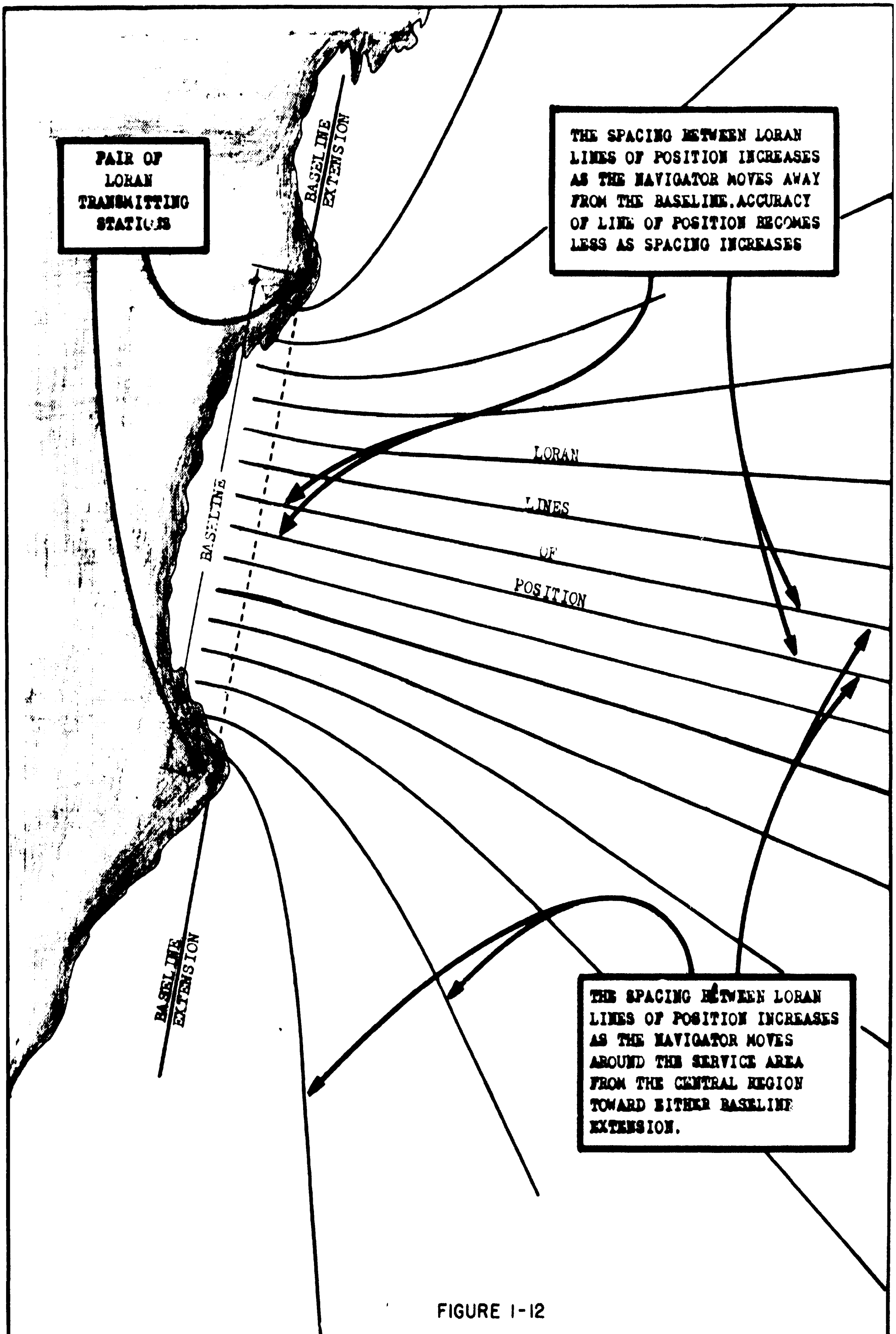

PAIR OF
LORAN
TRANSMITTING
STATIONS
BASELINE
EXTENSION
THE SPACING BETWEEN LORAN
LINES OF POSITION INCREASES
AS THE NAVIGATOR MOVES AWAY
FROM THE BASELINE. ACCURACY
OF LINE OF POSITION BECOMES
LESS AS SPACING INCREASES
LORAN
LINES
OF
POSITION
BASELINE
BASELINE
EXTENSION
THE SPACING BETWEEN LORAN
LINES OF POSITION INCREASES
AS THE NAVIGATOR MOVES
AROUND THE SERVICE AREA
FROM THE CENTRAL REGION
TOWARD EITHER BASELINE
EXTENSION.

FIGURE 1-12

principle. This quality is known scientifically to be the most stable and unchanging electrical characteristic of radio waves and consequently the loran system stems from a firm and proven scientific foundation.

The outstanding features of the loran system may be summarized as follows:

(1) Loran fixes may be obtained readily at long distances from the transmitting stations. The daytime range is approximately 750 nautical miles and at night a range of 1,400 nautical miles is realized. In addition to the range of individual pairs of stations, the integrated loran system is so arranged that coverage is available over all of the major shipping lanes of the world.

(2) The accuracy of loran fixes is of high order. Results comparable to those obtained by means of good celestial observations are consistently effected.

(3) Loran operation is very nearly independent of the weather. It is not affected by conditions of the sea or air and does not suffer from the doubtful effects encountered with older types of radio navigational devices such as direction finders, etc.

(4) The time required to obtain a loran fix is short. Experienced operators usually take from 2 to 3 minutes to establish a fix.

(5) Operation of loran shipboard and aircraft equipment is relatively simple and navigators may be trained in loran technique in only a few days time.

(6) Efficiency of long-range navigation is increased. The course sailed may be more direct with a resultant saving in fuel and increase in pay load.

(7) Landfalls may be made at points close to the destination of a vessel.

(8) Loran fixes are independent of other navigational instruments such as compass, chronometer, and other radio equipment. No transmission from the vessel or aircraft is required and only a single item of equipment is used which may be installed at any point convenient for the navigator.

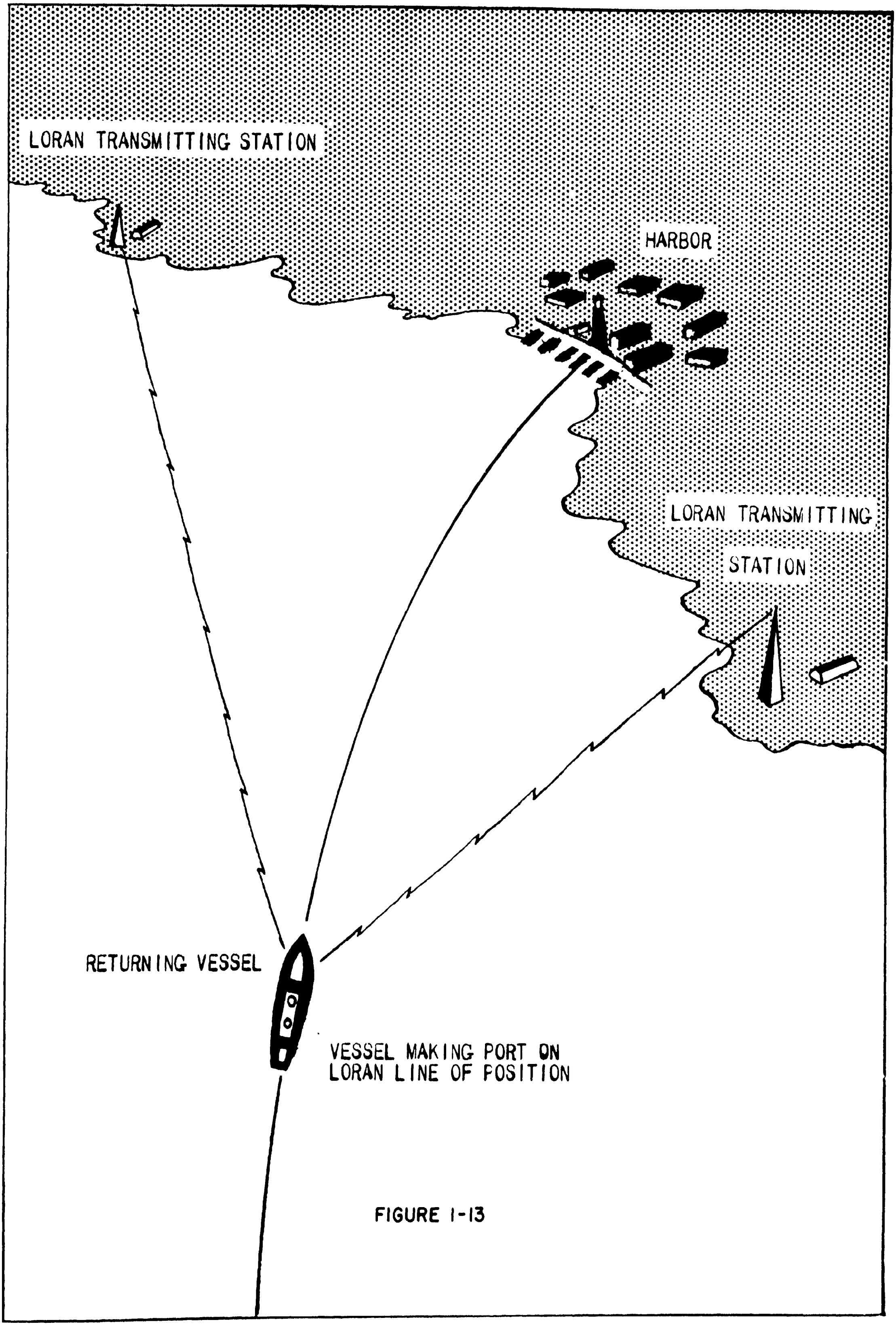


FIGURE 1-13

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(9) Safety at sea is greatly increased through Loran, and in case of disaster, rescue operations are direct. A minimum of time is lost in searching for disabled vessels when the loran position is included in the distress message. The increase in safety at sea will probably be reflected in reduced insurance premiums as the application of Loran becomes more widespread. This factor alone might easily compensate for the cost of the loran equipment.

Loran has already played a prominent role in rescue operations. Invariably distress at sea occurs during foul weather when determination of position by celestial observations has been impossible for several days. Under such limitations, the distressed vessel's dead reckoning position may be considerably in error. Late in 1946, in the Aleutian area, a distress case occurred which well illustrates the value of Loran in the saving of life at sea. Surface vessels and aircraft were engaged in search operations for a barge foundering in heavy seas with 8 persons aboard. Positions transmitted by radio from the barge, 24 hours apart, were hundreds of miles different though the craft was not under power. This indicated that she did not have a reasonably correct knowledge of her position, and rescue operations were fruitless. After about 1½ days search, the barge was eventually located by plane. Fortunately the plane had Loran aboard, and quickly determined the barge's position from loran observations. After transmission of the loran determined position to surface vessels, the distressed craft was located and all hands rescued in a matter of hours before the water-filled barge sank during 70 mile per hour winds.

Thus Loran, through the medium of electronic science, constitutes a fundamental supplement to other methods of navigation, in assisting and protecting lives and property at sea.

SOME FACTUAL COMMENTS BY USERS

THE FISHERMAN:---Loran saves time because trial and error methods of locating the desired fishing grounds or bank by soundings are avoided. The master of a trawler reports that he can obtain a 3-line fix in less than 5 minutes. He also says that it is possible to obtain a fix whenever the net is set out, and again when it is hauled back about one and one-half hours later. This gives the exact distance traveled, which is a great help in keeping on the best fishing grounds. With an accurate knowledge of the trawler's position at all times, damage to nets and other equipment is minimized. Loran makes it possible to rush the catch to market with the least possible delay.

THE PASSENGER LINER:---Comments one navigator: "During our first crossing with Loran, we ran into some very stormy weather. In one instance, for example; we were unable to establish our position by means of celestial observation for a period of three days owing to overcast. I was mighty happy to have Loran aboard during this period as we depended solely on it for determining our position."

THE AIRLINER:--- As of March 1, 1947, at least twenty-one "scheduled" extended overwater flights arriving or departing Honolulu make use of Loran in the Pacific Ocean. Pan American Airways, for example, has equipped all of its planes in that area with Loran. P.A.A. flights are as follows:

San Francisco to Honolulu	2 flights daily
Honolulu to San Francisco	2 flights daily
Honolulu - Southbound	3 flights weekly

LORAN SYSTEM DESCRIPTION

(Note.--The technical aspects of the loran system are described in this section for purposes of completeness, to be used for the information of persons who may have occasion to study Loran in some detail. The material presented is in tabluar form and is not considered to be of interest to the majority of readers of this publication.)

LORAN: A long range aid to navigation for the determination of position based upon the difference in times of arrival at the navigator's position of radio signals transmitted from two fixed loran transmitting stations.

TYPE OF TRANSMISSION: Loran transmissions are "pulse" transmissions. Very short pulses of radio frequency energy are radiated at periodic intervals which are very long compared to the duration of the pulse. During the interval between successive pulses of a station, no radio signal from that station is on the air.

RADIO FREQUENCY: Loran signals are transmitted at the present time on three frequency channels:

1950 kilocycles.
1850 kilocycles.
1750 kilocycles.

PULSE DEFINITION: The loran pulse signal is of approximately 80 microseconds duration and the rectified envelope has a shape similar to that of a sine wave when viewed on a loran receiver. It is customary to measure pulse width at one-half amplitude; standard width is thus considered to be 40 microseconds.

PULSE REPETITION RATES: Loran pulses are transmitted at a number of different repetition rates. Differences in repetition rate is the means of identification of particular pairs of stations. Specific pulse repetition rates are assigned in several general categories with the particular rates of each category being only slightly at variance with a convenient rate known as the "base rate." Present "base rates" and "specific repetition or reccurrence rates" are tabulated below:

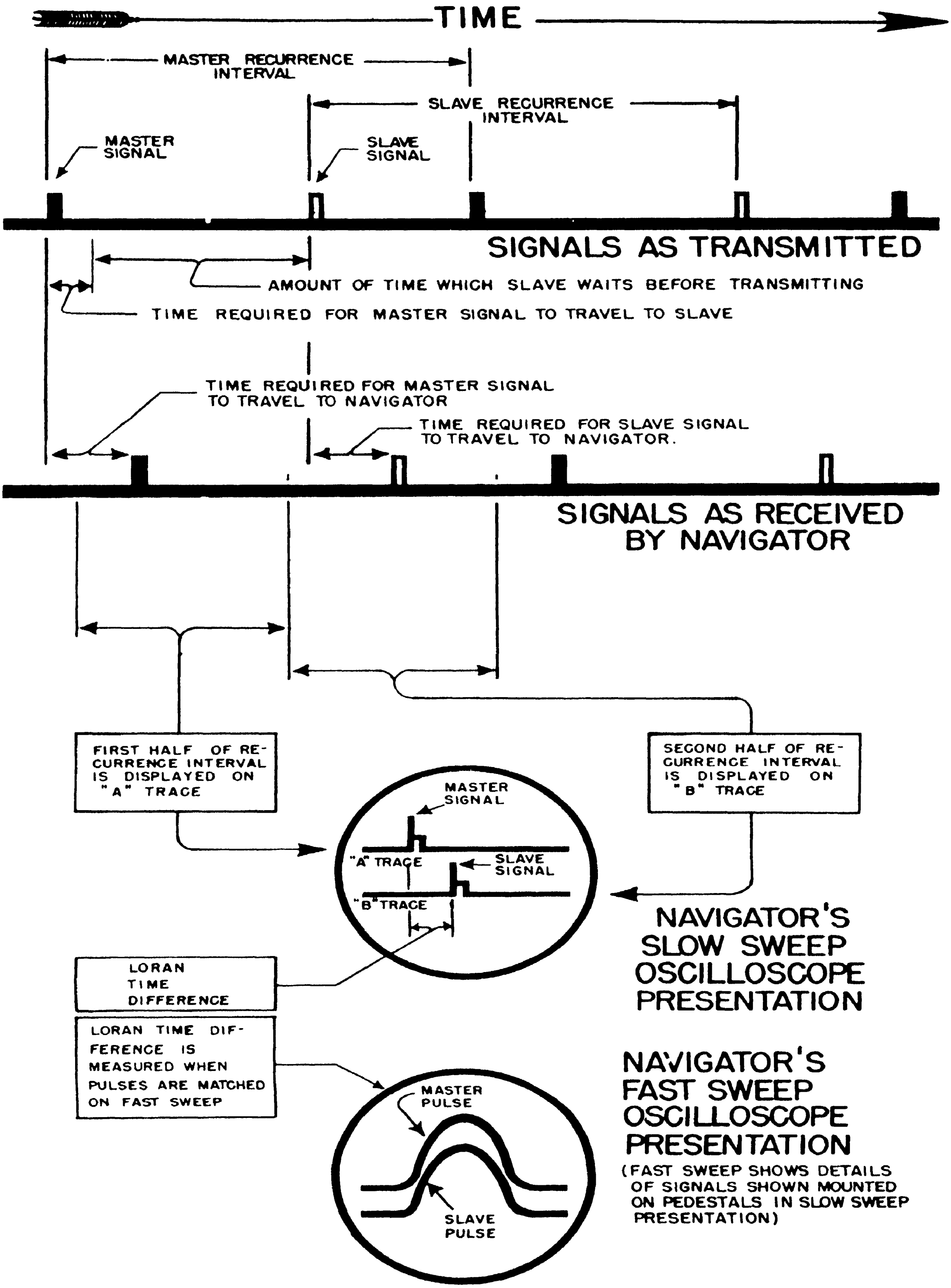
BASE RATE 25 CYCLES (PULSES) PER SECOND		
Specific rate designation	Frequency cps	Interval, microseconds
0	25	40,000
1	25 1/16	39,900
2	25 1/8	39,800
3	25 3/16	39,700
4	25 1/4	39,600
5	25 5/16	39,500
6	25 3/8	39,400
7	25 7/16	39,300

BASE RATE 33 1/3 CYCLES (PULSES) PER SECOND		
Specific rate designation	Frequency, cps	Interval, micro-seconds
0	33 1/3	30,000
1	33 4/9	29,900
2	33 5/9	29,800
3	33 2/3	29,700
4	33 7/9	29,600
5	33 8/9	29,500
6	34	29,400
7	34 1/9	29,300

New loran transmitting station equipment is capable of operation on a base rate of 20 cps to provide for future expansion of the system without requiring additional radio frequency allocations.

LORAN TIMING SEQUENCES:

(Loran timing sequences are shown graphically in fig1-14). Master and slave stations are pulsed at exactly the same pulse recurrence rate. The master pulse is transmitted first and, after traveling the distance of the base line, arrives at the slave where it is received and used as a timing reference. After waiting for a predetermined length of time which is necessary to establish correct loran synchronization, the slave station transmits its pulse. The amount of time that the slave waits, or delay, is always fixed at an amount greater than one-half of the recurrence interval, and, as a consequence, the master signal is always transmitted during the first half of the recurrence interval and the slave transmission always occurs during the second half of the interval, regardless of the navigator's position with respect to the stations. The signals are received and viewed by means of a cathode ray oscilloscope using a time base equal to the recurrence interval but divided into two equal half-interval traces so placed on the scope by the sweep circuits that two half-traces appear with the first half directly above the second half. Both traces are horizontal in time sweep.



LORAN TIMING SEQUENCES

FIGURE 1-14

The controls of the receiving instrument are adjusted until the master signal is viewed near the beginning of the upper, or "A," trace. The slave signal will appear in its proper place on the lower trace. Measurement of the loran time difference is made by evaluating the horizontal displacement of the slave station with respect to the master in terms of time, microseconds. By this physical arrangement of the traces the half recurrence interval delay which was introduced by the slave is effectually canceled from the measurement. Loran readings thus obtained may be interpreted in conventional coordinates by the use of loran charts or tables. A fast speed time base having a duration of roughly from 100 to 300 microseconds is provided to permit visual examination of the pulse envelope itself which is necessary to establish the precise adjustment required in making a loran reading.

BLINKER SIGNAL: The timers at loran transmitting stations are equipped to perform a function known as blinking. The signal is used to indicate that the transmissions should not be considered reliable during the period of blinking. In general, blinking causes the received pulse to rhythmically swing back and forth as viewed on the Slow sweep, and to rhythmically appear and disappear on the Fast sweep. In the few exceptions to this method, due to a difference in transmitting equipment, there is a rhythmic appearance and disappearance on both Slow and Fast sweeps.

LORAN RECEIVER-INDICATOR FUNCTIONAL SPECIFICATION

RADIO RECEIVER

OPERATING RADIO FREQUENCIES: The radio receiver of a loran receiver-indicator is provided with four radio frequency channels and may be set for operation on any of the frequencies tabulated in the system specification. In operation, receiver tuning is fixed and a four-position switch provides simple means of changing channels.

RECEIVER SENSITIVITY: The receiver has a sensitivity sufficiently high that a signal of approximately 10 microvolts delivered by the antenna to the receiver input will result in full scope deflection of the cathode ray indicator. Receiver and indicator form an integrated unit and are not intended to function separately.

BANDWIDTH: Early designs incorporated a total bandwidth of the order of 80 kilocycles at 6 db down. Current trends are toward considerable reduction and total bandwidths of 40 kilocycles or less at the same decibel limitation are contemplated.

DIFFERENTIAL GAIN AMPLIFIER: The receiver incorporates a differential amplifier which operates in synchronism with the incoming signal recurrence frequency to permit amplification of each of the two signals received at different ratios. This feature permits presentation to the cathode ray indicator of signals of equal amplitude. Sufficient range of operation is provided to permit accommodation of incoming signals having a ratio of strengths as high as 500 to 1. Earlier equipments had an operating limit of roughly 100 to 1.

INDICATOR

FUNCTIONAL PURPOSE: The indicator unit contains the necessary circuits to perform all of the timing functions of the equipment with the required precision. It contains the sweep generators and the cathode ray tube for presentation of the signals received.

MASTER OSCILLATOR: The basic timing medium of the equipment is a precision, crystal controlled, master oscillator. The oscillator possesses a high order of short time stability in the order of a few parts in 10 million. Manual means of adjustment is provided to vary the frequency over a range of more than 200 parts in a million. This adjustment permits

cycling the oscillator until the timing of the receiver-indicator is in exact step with the recurring pulses received from the transmitting stations.

TIMING MARKERS: Through the medium of its timing circuits, the indicator provides a sequence of precise timing markers spaced at convenient intervals to facilitate measurement of time sequences with a basic accuracy in the order of plus or minus 1 microsecond.

TIME BASE: The sweep generators provide a slow sweep as outlined in the system specification which covers the entire recurrence interval by means of a divided trace. A fast sweep lasting in the order of 200 microseconds or less is provided and by means of delay controls may be positioned to examine the particular section of the time base at which a signal appears. For convenience in identification and for purposes of triggering and delay measurement a pedestal or raised rectangular pulse appears on the slow sweep presentation in the portion covered by the fast sweep. Timing arrangements are made to permit the fast sweep generator to fire at a predetermined point on both the upper and lower traces.

MATCHING PULSES: To measure loran time differences, the time base is cycled with respect to the transmissions until the master and slave signals appear at convenient points on the upper and lower traces, respectively, with adjustment being made such that the fast sweep generator fires precisely in the region of both signals. Thesignals are examined on the scope operating on fast sweep and a fine adjustment is made until the pulses are superimposed or matched with respect to time. Time difference measurements are made by means of timing markers.

EQUIPMENT POWER REQUIREMENTS: Loran receiver-indicators for shipboard installation are designed to operate on 115 volt (nominal) 60 cycles, single phase, alternating current, are

rated at from 200 to 300 watts.

Aircraft equipments are made to operate on voltages of from 80 to 115, single phase, alternating current, and on frequencies from 360 to 2,460 cycles. Equipments are rated at less than 200 watts.

RECEIVING ANTENNA:

Receiving antenna installation is simple since only a vertical wire is required. A length of 50 to 60 feet is considered desirable although satisfactory operation is experienced when physical conditions require considerable decrease in the effective antenna length.

METHOD OF OBTAINING LORAN READINGS

The majority of loran receiver-indicator equipment now in use was that developed and manufactured during the war. This equipment requires that time difference determinations's be made by matching master and slave pulses and then by switching to additional scope selection positions and by reference to a set of markers, count the divisions and thereby arrive at the reading. Receiver-indicators now being manufactured and installed which incorporate direct reading counters, so that once the pulses are matched, all that is necessary to determine the time difference reading is to refer to a counter device which shows directly the proper numerical reading. Equipments under development for future use contemplate automatic matching of pulses as well as the direct reading counters.

CHAPTER TWO

RADIOBEACON SYSTEM

INTRODUCTION

An important advance toward greater safety and efficiency in navigation has come about in the last 24 years through development of an extensive system of radiobeacons.

The coast may be blanketed in fog, all visible signals may be shut out by rain or snow, all sound warnings may be drowned by storm, and yet the navigator may with confidence take bearings on radio signals at distances which will vary with the class of radiobeacon on which a bearing is taken from 10 miles to over 200 miles. For over 2000 years there have been lighthouses to guide ships, and for more than 200 years there have been fog warnings of some sort to aid the mariner in thick weather, but until the introduction of radiobeacons he has never had a practicable method of taking accurate bearings on invisible objects. Radio has supplied this most urgent need of navigation by providing a reliable means of taking bearings regardless of the condition of the weather, a means not limited as to distance as are sight bearings, by the curvature of the earth, or by the candlepower of the light. This system has contributed greatly to the safety and efficiency of vessels, and it constitutes one of the most important advances that has ever been made in the science of navigation.

Every mariner and every person who travels upon the sea owes thanks to radio for its many contributions to increased safety. The earliest application of radio to safety at sea was communication between ship and shore which has been the means of saving the crews and passengers of many foundering vessels which otherwise would have been listed simply as "missing." Incidental to this came the broadcasting over the whole sea area of accurate time and weather warnings, giving the mariner a frequent check on his chronometer and on weather conditions. Now the system of navigation from radiobeacons, by means of bearings taken from direction finding equipment on shipboard, has become well established as a most important method of enabling vessels to check their positions. Only 26 years ago, in 1921, the first successful radiobeacons were established in the approaches to New York.

Radiobeacon navigation is not restricted to bearings on regularly established radiobeacon stations as the same navigation principles apply to bearings on any fixed radio station whose position

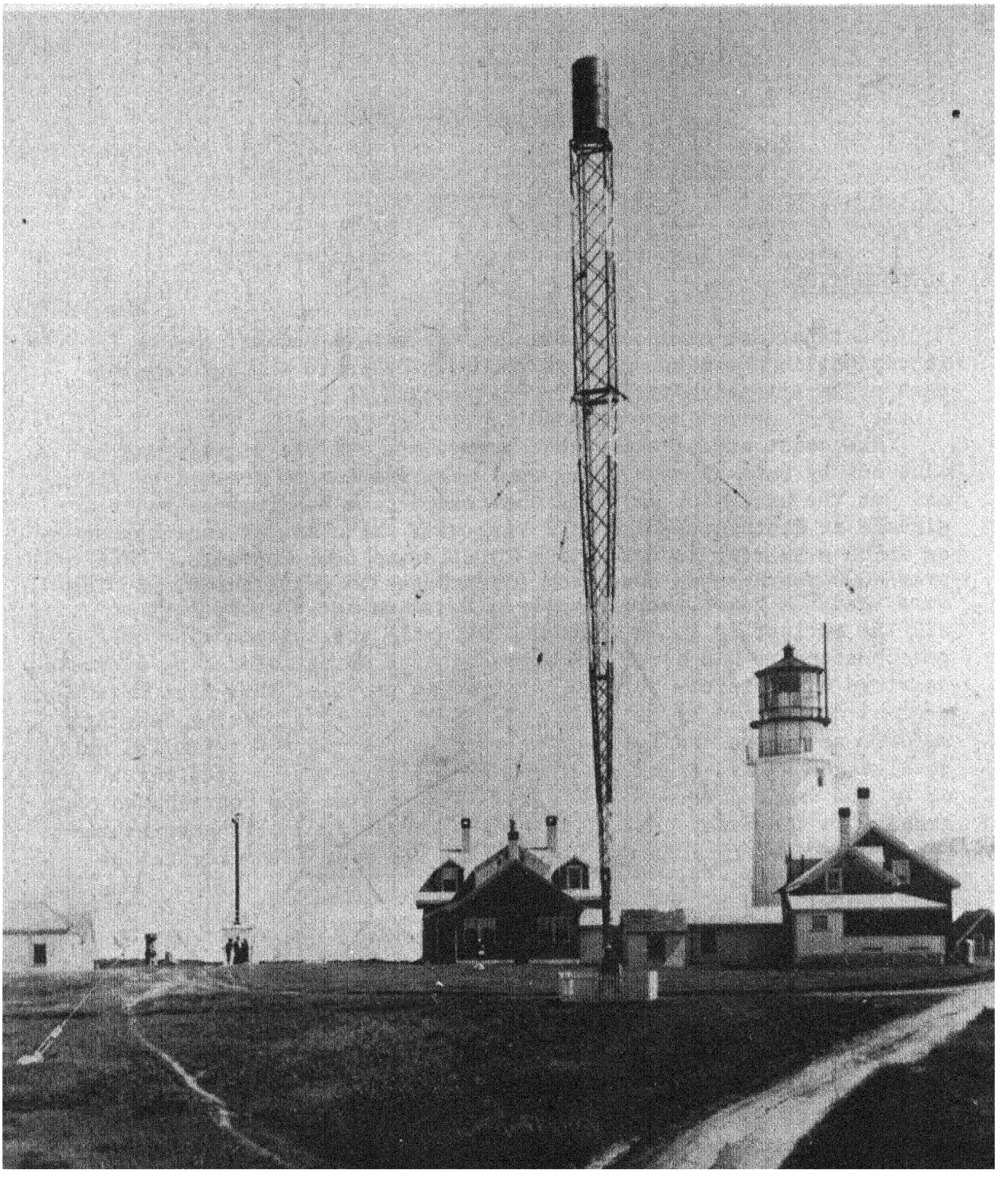


Figure 2-1. — Cape Cod Light Station, Massachusetts. Established 1798. Rebuilt 1857. Top of lantern 66 feet above ground. Light 183 feet above water. Foundation: rubble stone masonry. Signals: first ord[illegible]tric apparatus. Flashing white every 5 seconds. Flash 0.2 second, eclipse 4.8 seconds. 13,000 candlepower. High-power class A radiobeacon. Special antenna in foreground. Fog signal: horn, diaphragm, electric; blast 3 seconds, silent 12 seconds.

is known, or on any mobile radio station, as another ship whose position has a significance in the navigation of the observing vessel.

RADIOBEACON SYSTEM OF THE UNITED STATES

There were on April 1, 1947, in operation on the coasts of this country 186 radiobeacons, (Fig. 2-2), constituting a large system of aids to navigation. This system, operated by the United States Coast Guard, is important among the system of lights, buoys, and other systems of aids, the maintenance of which is one of the principal functions of the Coast Guard. Radiobeacons add greatly to the completeness of aids to navigation systems and fill an important gap in previously available facilities. The United States maintains far more radiobeacons than any other one country.

Because of the many factors affecting navigation it is somewhat difficult, from an analysis of statistics, to show the effect of radiobeacon navigation in the way of increasing safety, but the following figures are of interest. On the Great Lakes the benefits from radiobeacons were remarkably effective for the four years 1927-1930. In this period there were 31 strandings in a group of 470 vessels, or one for each 15 vessels. For the four years 1923-1926, before the advent of radiobeacons, there were 76 strandings in a comparable group of 572 vessels, or one stranding for each 7.5 vessels. Shipping interests state that the influence of radiobeacon navigation was an important factor in the reduction thus shown.

Further developments in equipment and in methods of use for radiobeacons are always under consideration for the improvement and development of the radiobeacon system.

RADIOBEACON NAVIGATION

Radiobeacons are radio stations installed at lighthouses, on lightships, or at other points shown on the charts, for the sending out in all directions of radio signals, for the purpose of guiding marine navigation. Radio direction finders are special radio receivers with rotating coil antennas installed on vessels by means of which bearings are taken on stations sending radio signals.

When first introduced, these installations were called radio fog

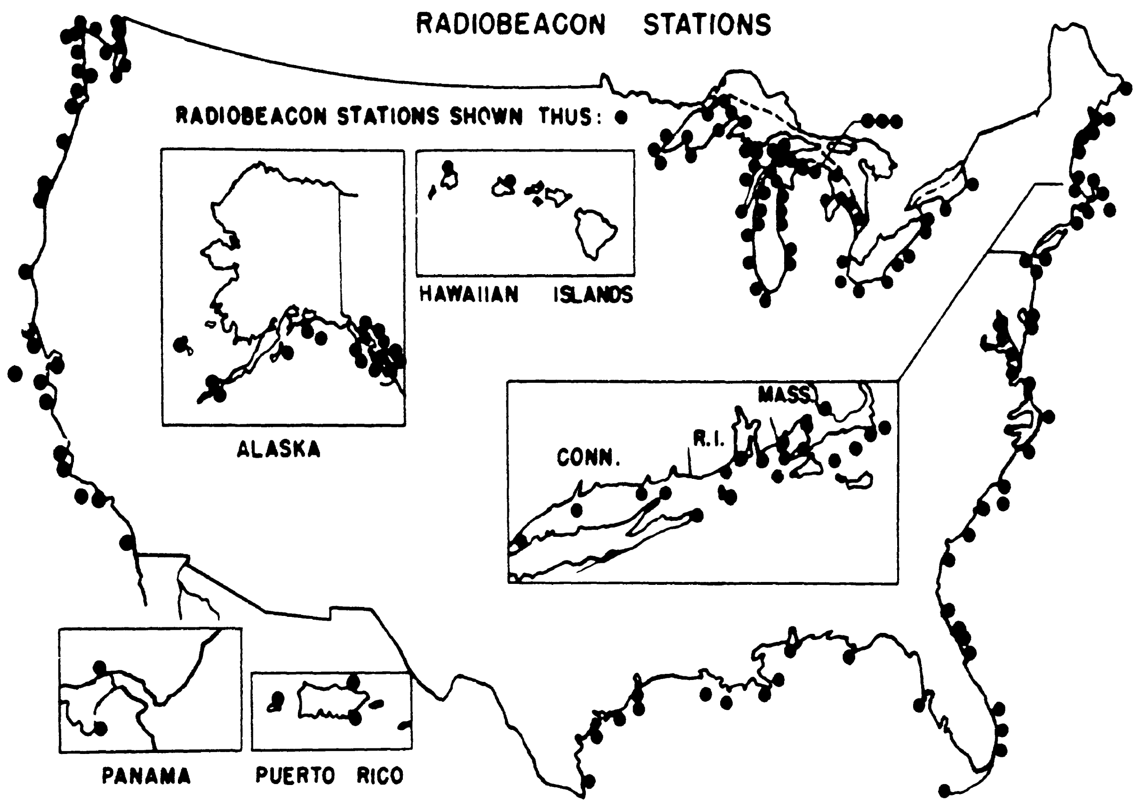


FIGURE 2-2. THE MARINE RADIOBEACON SYSTEM OF THE UNITED STATES, 1947.

signals or wireless fog signals, as they were originally planned for use in fog; but they have developed, as will be described, into valuable aids in either fog or clear weather; therefore, the restrictive name "radio fog signal" was considered inappropriate.

In this country, the direction finding equipment on shipboard is nearly always installed in such a way and the transmitted characteristic signal is such that the navigator himself can conveniently take distinct and easy-to-recognize radio bearings. The general problems and practice of navigation are then the same when using radio bearings as they are with visual bearings on lighthouses or other known objects. The practical differences between radio and sight bearings are not differences in principle, but in the availability of the former at much greater distances and under all conditions of visibility or fog. The radiobeacon is located at a definite point shown on the chart; it sends out signals by radio in all directions around the horizon, as does a lighthouse by means of light beams; and it is distinguished from the neighboring signals by a definite characteristic, as is also the light.

The radiobeacon may be used as a leading mark for which to steer directly, the navigator correcting the course from time to time by successive radio bearings. Thus, such a signal off an entrance or other objective may be approached with certainty from a considerable distance. This is a very valuable use of radiobeacons, especially when these signals are located on lightships, as is well illustrated by the signals on Nantucket Lightship and Ambrose Lightship, which guide trans-Atlantic vessels to the approaches of New York Harbor.

The signal emitted by a radiobeacon follows a great circle course. Radio bearings may be plotted without applying a correction on a Mercator chart if the difference in longitude involved is not in excess of one or two degrees. When the difference is larger, a correction usually must be applied which will be found in H.O. Publication No. 205. "Radio Navigational Aids," under Radio Bearing Conversion Tables.

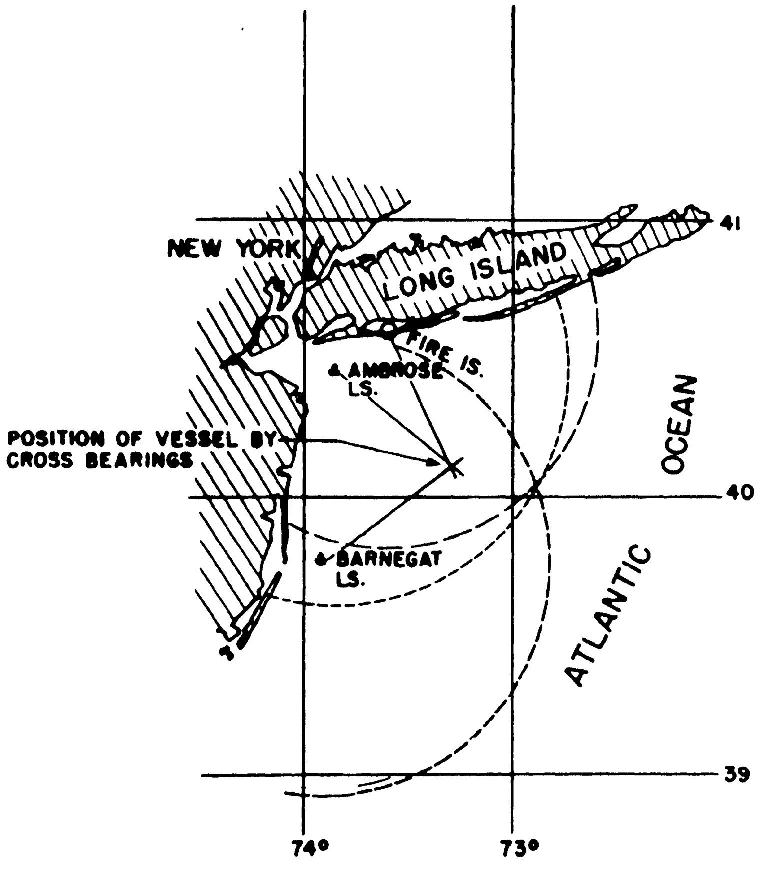


FIGURE 2-3. RADIOBEACONS IN THE APPROACHES TO NEW YORK AND HOW THEY MAY BE USED BY VESSELS.

A bearing from a radiobeacon station may be combined with information from other sources, as from an intersecting line of position from an astronomical observation, from soundings, from dead reckoning, etc., to locate the position of the vessel.

A ship may also be located by radio bearings on a single radiobeacon by taking two bearings on a station with an intervening period of time and plotting these with respect to the distance and course run between bearings. With radio bearings, because the signals are not operating continuously excepting during fog, advantage should be taken of bearings at suitable angles as opportunity offers.

The common method of locating a ship by cross bearings may be employed in radio navigation using two or more radiobeacons, or visual and radio bearings in combination. Of course, the usual principles apply as to employing stations which will give good intersections and as to allowing for the distance run between the times of taking bearings, if the interval is appreciable.

United States radiobeacons are operated at intervals on a fixed time schedule in clear weather and continuously during fog; adjacent stations send for successive minutes. This facilitates the taking of radio cross bearings, as does also the location in important localities of two or three stations sufficiently close for cross bearings.

Radiobeacons in the approaches to New York, illustrating their use in navigation, are shown in Figure 2-3. Figure 2-4 illustrates how in actual practice a navigator may fix his position by cross bearings on three Pacific coast radiobeacons. The angles between the stations in Figure 2-4 are not such that a small triangle of most probable position will be formed as in Figure 2-3. Such cases are common along some steamship routes, but the fixes are extremely valuable, nevertheless, and may be good despite the small angle at which two of the lines cross. It will be noted that in Figure 2-4 the correctness of the bearing of the station to the north is confirmed or independently checked by that of the station to the south to give the distance off-shore, while the bearing of the station to the east gives a cut at a good angle to determine the progress of the vessel along the coast.

For additional information on accuracy of bearings, plotting, and other matters, the navigator should consult the current issue of H.O. Publication No. 205, "Radio Navigational Aids."

Radio bearings from a ship may, of course, be taken on any sending station shown on the chart, transmitting on a frequency within the range of the direction finder receiver. A considerable

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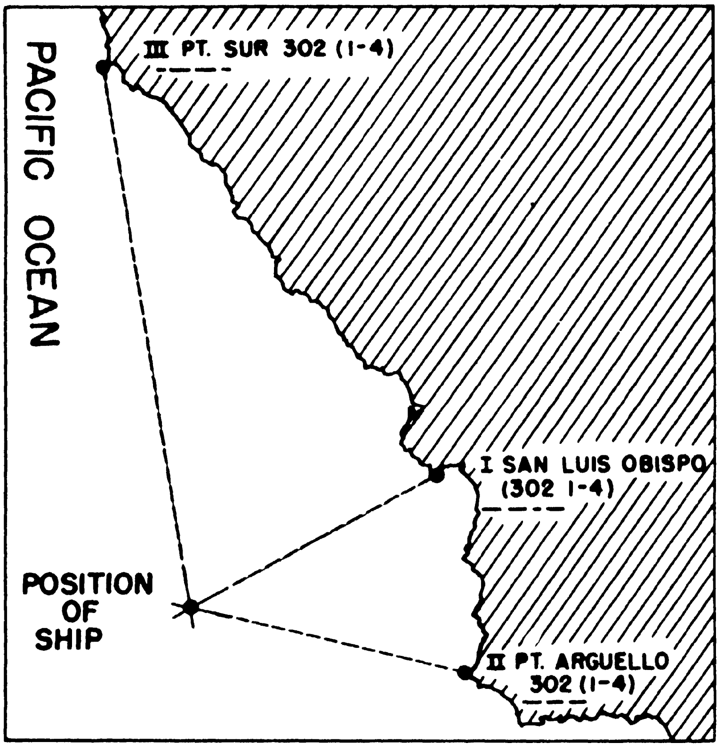


FIGURE 2-4. DETERMINATION OF SHIP'S POSITION FROM THREE GOOD RADIOBEACON BEARINGS PLOTTED ON THE CHART.

number of such radio stations throughout the world have been listed, on which bearings may be taken from ships equipped with radio direction finder equipment, and many of these stations will, on request, transmit signals to permit radio bearings being taken. However, because of their dependable and convenient operating system, it is more satisfactory in navigation to use bearings on the radiobeacons specially established for this purpose.

A number of cases have been reported of the indirect use of radio bearings in navigation. A vessel equipped with a radio direction finder and knowing its own position has been able to assist other vessels by means of radio bearings. Thus, where a vessel seeking another in distress is unable to locate it because of inaccurate reported position, neither having a radio direction finder, a third vessel so equipped has been able to guide the rescuing vessel by the use of radio bearings.

There has, in the past, been discussion of the relative merits of using radio bearings obtained from the ship and from fixed radio direction finder stations on shore, but the question was of importance only in the development stage. As soon as the improvement of the marine radio direction finder made practicable the obtaining of reliable radio bearings from the ship, the advantages became apparent of having such a valuable navigational instrument located so as to be directly available to the navigator for the various and general uses to which it may be applied on shipboard. This system conforms to the standard practice of the sea in retaining the location of the navigating instruments on the ship and placing the responsibility for their use and for the navigation of the ship in the hands of the master. The navigator can use such checks as he deems best, and knows what reliance to place on radio bearings in comparison with his other means of guiding the vessel. Any number of vessels properly equipped may take bearings simultaneously on a radiobeacon, just as they can on a lighthouse, without interference with each other.

The direction finding equipment on shipboard (see Fig. 2-5) has come to be recognized as a navigational instrument essential to all larger vessels, and has been extensively installed on smaller vessels. Its use tends directly to economy of operation, and to increased safety.

The International Conference on Safety at Sea, held at London in 1929, prescribed that, within two years after the convention had been in force, every passenger ship of 5,000 tons gross tonnage and upward should be provided with an approved radio direction finding apparatus (then called a radiocompass).

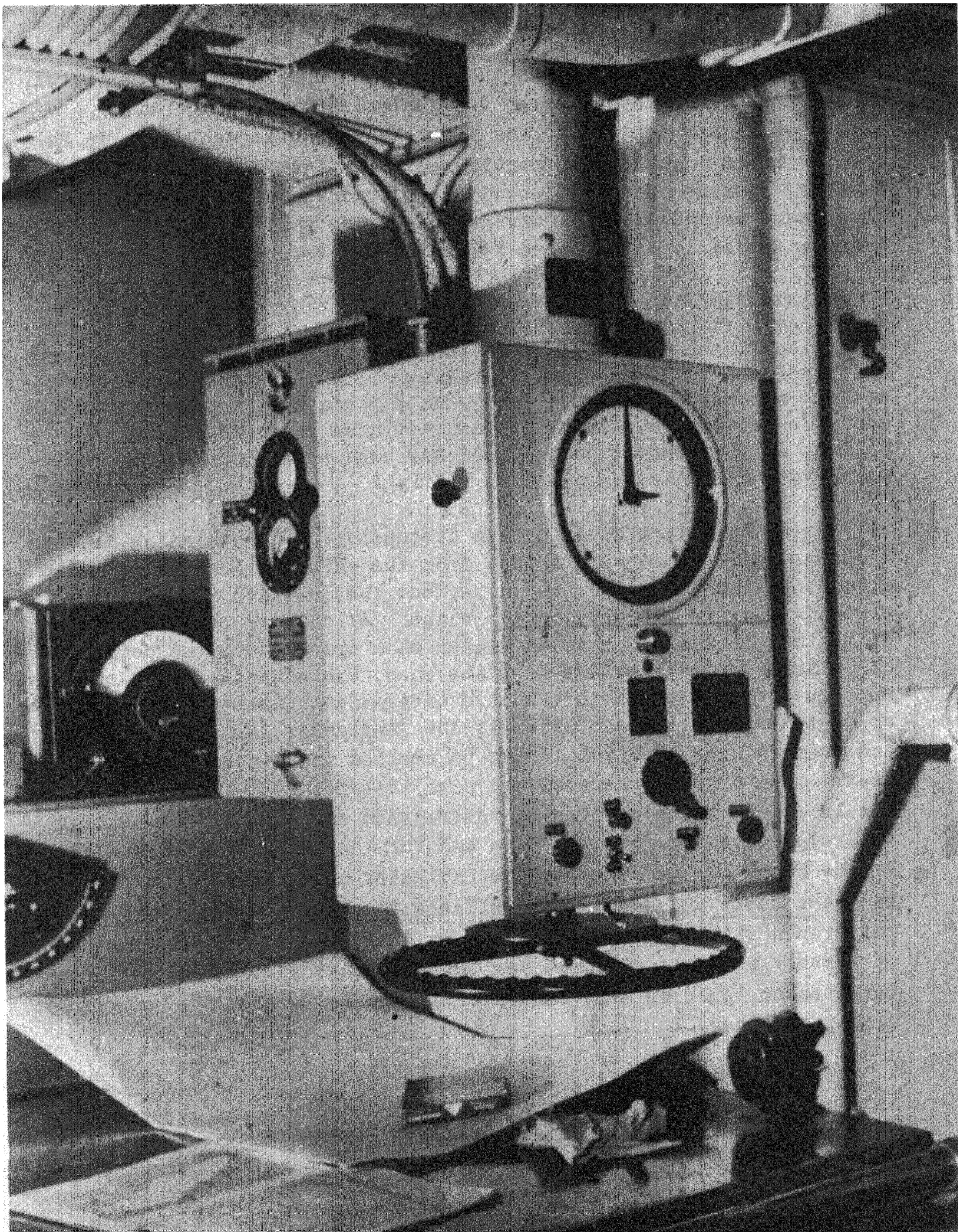


Figure 2-5. — A modern radio direction finder installed aboard ship.

The use of radiobeacons greatly aids a navigator either to follow a desired or prescribed course, or to avoid a congested route. It has been reported, for example, that since this system came into service, steamers on Lake Superior have been better able to adhere to the west and eastbound traffic lanes agreed upon on that lake.

The use of radio bearings taken on board ship may result in considerable saving of time. Besides the particular value of this in rescue and relief work, it also increases the efficiency of operation of the vessel. It is frequently possible by means of radiobeacon bearings to make port in fogs which formerly have prevented the ship from proceeding.

The use of radiobeacons on inland waters has received a thorough test on the Great Lakes, Long Island and Vineyard Sounds, and Chesapeake Bay, where they have proved most valuable.

LOCATION AND DISTRIBUTION OF RADIOBEACON STATIONS

Radiobeacons are located at various sites (shore and marine) so that they may be of utmost usefulness to the mariner in locating his position. (See Fig. 2-2). On account of their much greater range it is evident that the general needs of navigation in this respect for any given length of coast have been supplied by a much smaller number of stations than are required in respect to lighthouses, or to sound fog signals.

In the United States the regular radiobeacons are divided into three general classes, as follows:

Class A - Reliable average range of 200 miles.

B - Reliable average range of 100 miles.

C - Reliable average range of 20 miles.

Cape Cod Radiobeacon, Massachusetts, and Point Arguello Radiobeacon, California, are high power Class A radiobeacons which have effective ranges of about 400 miles.

In addition to the above there is a Class D marker radiobeacon of low power with an average range of 10 miles, for local use only, which operates continuously with special characteristics.

The most powerful sound-in-air fog signals under favorable conditions may be heard at distances of 10 to 15 miles, but their

ordinarily dependable range is not over 5 miles, and, under unfavorable conditions, they are lost at distances shorter than this. The coast lights are visible for from 15 to 20 miles and large lighted buoys for about 9 to 12 miles. It is therefore readily seen that the radiobeacons have a much greater range of usefulness, in fog as well as in clear weather. This is well illustrated by the fact that on the outside Atlantic Coast of the United States, north of Cape Hatteras, there are but 19 radiobeacons. This length of coast requires five times this number of sound fog signals, and they are effective over only 2 percent of the area served by the radiobeacons. The same length of coast has 150 outside lights.

In order to lessen interference, the power of radiobeacons is limited to that which is necessary, according to the various purposes of the stations. For the same reason the primary stations are restricted to a few widely separated points of strategic importance to navigation, which are valuable as landfall stations or for long distance approach.

Local, low-power radiobeacons have been placed on inside waterways, such as Strait of Juan de Fuca, Long Island Sound, and Chesapeake Bay, but the greater number of radiobeacons are of intermediate power, and are located and spaced to meet the usual requirements, both for coastwise and lake navigation, and for approaching entrances. These signals are now sufficient in number so that a vessel near the coasts of Continental United States or on the Great Lakes will always be within range of one of these signals and usually two or more of them.

Radiobeacons are now recognized to be all-weather aids to navigation, instead of simply fog signals as originally suggested. They permit bearings to be taken on stations invisible on account either of thick weather or of distance, and they add tremendously to the effectiveness of systems of aids to navigation.

In general, radiobeacons are located at all important entrances and at outstanding intermediate points along the coast. There are only a few that have not been placed at established lighthouses or on lightships. This is advantageous because such positions are shown on the charts and are well known to mariners and because this is the most economical arrangement, both as to installation and operation of radiobeacons. (See Fig's. 2-6, 2-7 and 2-8).

Lightships have been found to be the most valuable and convenient stations for radiobeacons. They are in the positions of greatest importance to the navigator, and they may be steered for directly and passed on either side. All lightships have radiobeacons.

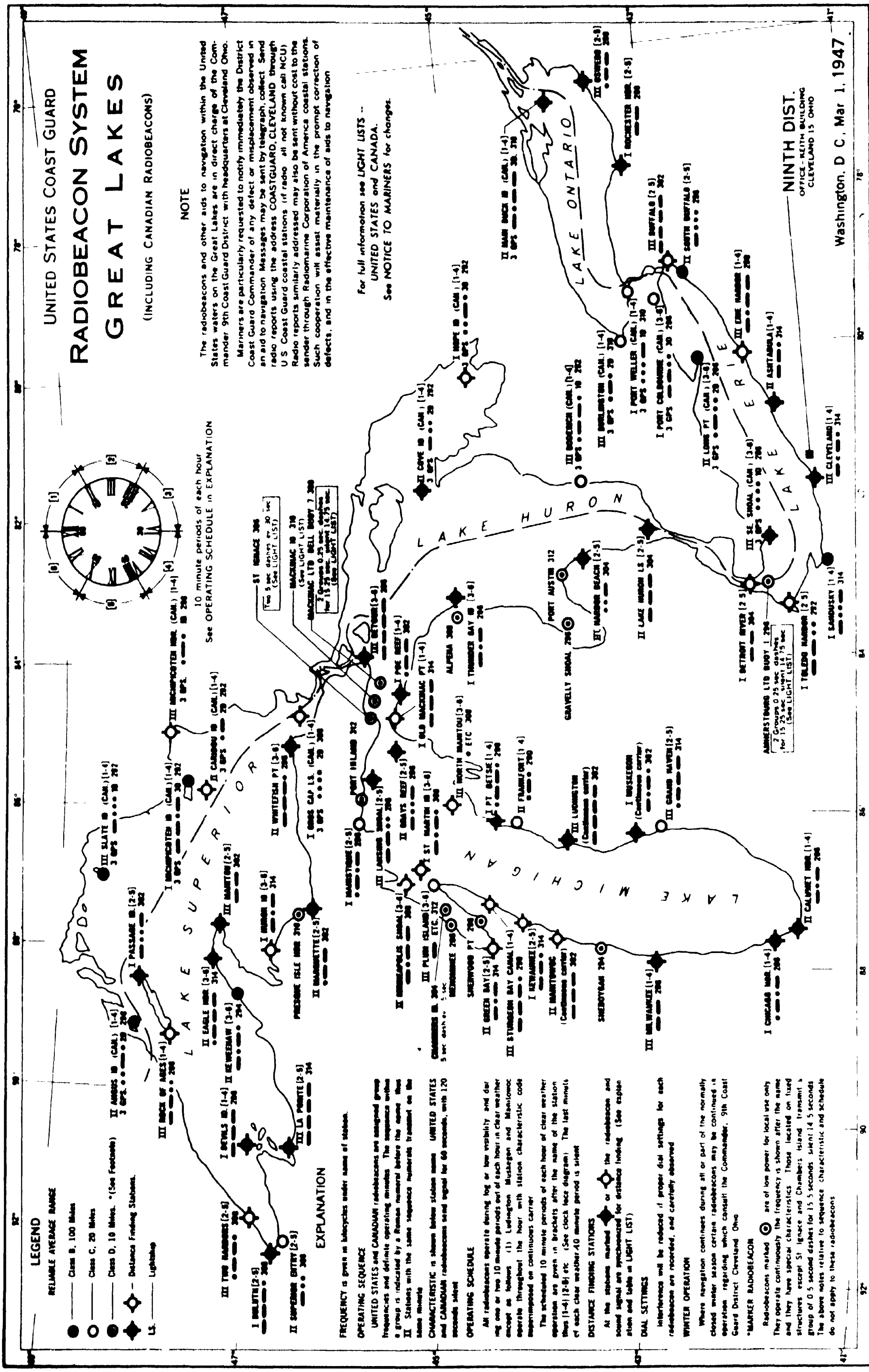


Figure 2-6. — Radiobeacon System, Great Lakes

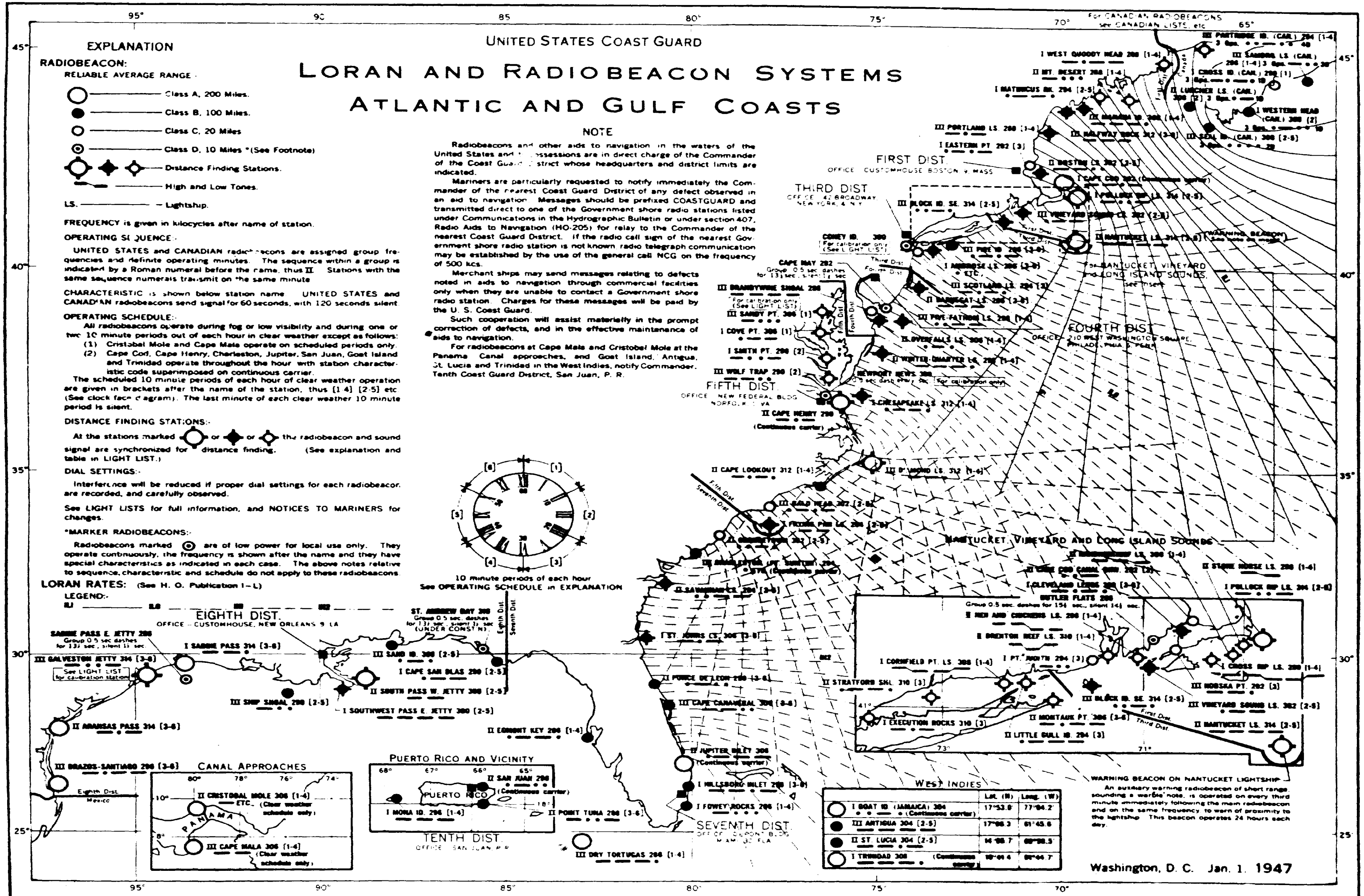


Figure 2-7. — Radiobeacon System, Atlantic and Gulf Coasts.

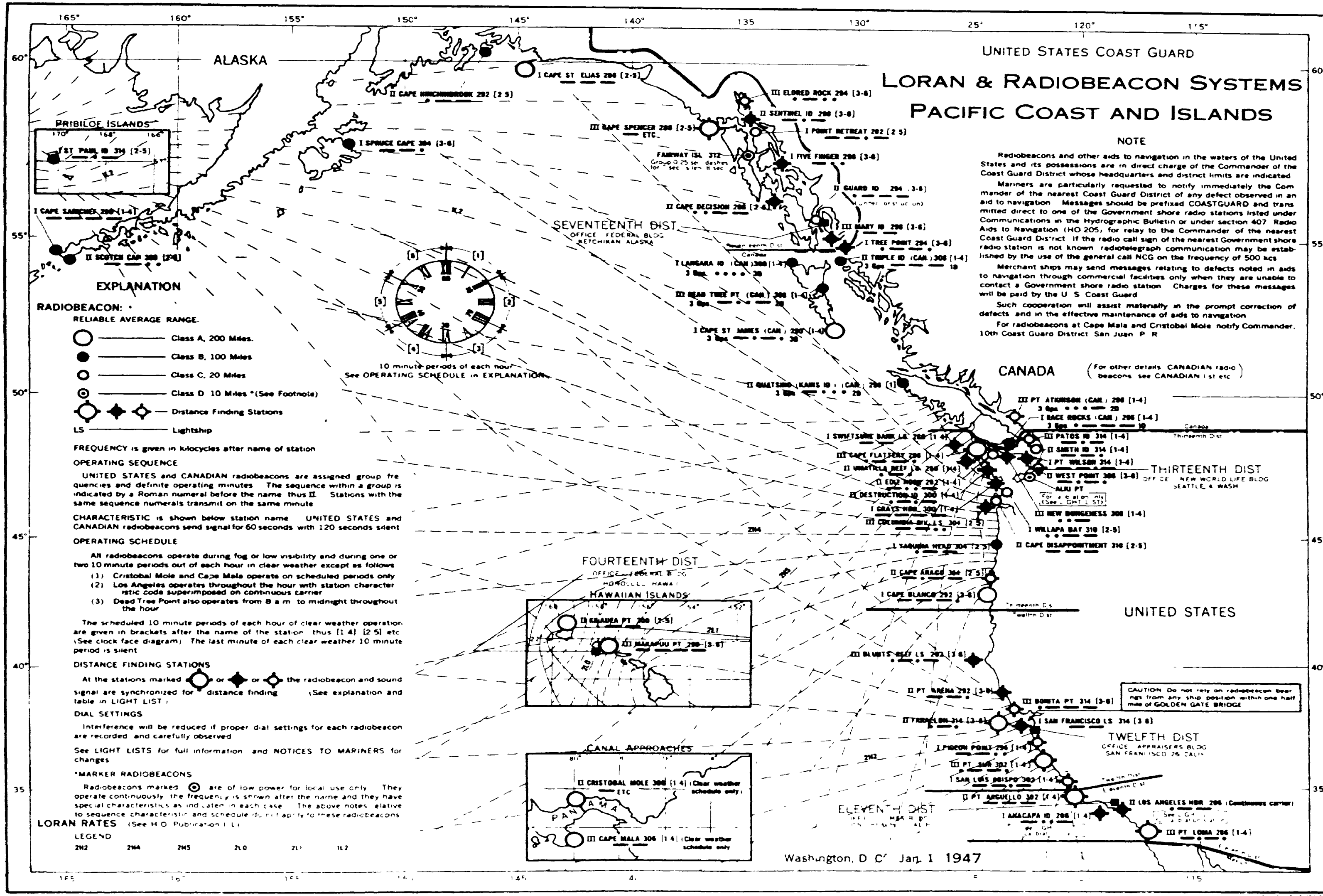


Figure 2-8. — Radiobeacon System, Pacific Coast and Islands.

In this country, during periods of good visibility, radiobeacon signals are sent out for one minute out of each three minutes, for one or two 10-minute periods each hour. During fog and low visibility they are operated continuously.

It would be convenient to the navigator to have long, continuous operating periods, or even to have the radiobeacons send continuously without any silences, thus making these aids to navigation always available, as are lighthouses and buoys. The system that is in use is a compromise, adopted to lessen interference. Masters of vessels who understand the necessity of the simple plan of operation are satisfied with the system and many letters have been received by the Coast Guard confirming this statement.

Vessel operators may request and obtain the continuous operation of a radiobeacon for purposes of calibration of ship radio direction finder equipment, providing calibration is undertaken during the station's clear weather operating schedule and providing no other radiobeacon station in the same frequency-sequence group is observed in operation at the time.

Accurate timing of radiobeacon signals is accomplished by a signal timer which in turn is controlled by a primary clock. (See Figure 2-9). The latter is checked frequently against Naval Observatory time signals, thus making possible the grouping of stations with a minimum of interference. In addition, the signal timer at the light station controls all timed aids to navigation signals and the starting and stopping of the equipment necessary to make these signals. The signals and equipment include distance finding sound signals, main light, radiobeacon, engine generator starting, and warming transmitters, all controlled in their proper sequence.

FREQUENCY BAND RESERVED FOR RADIOBEACONS

The International Radiotelegraph Conference at Washington in 1927 in the regulations attached to the convention, provided that radiobeacons "shall use waves of 285 to 315 kilocycles per second (1050 to 950 meters)" of the types continuous wave, or modulated continuous wave. This provision is now recognized by all countries concerned.

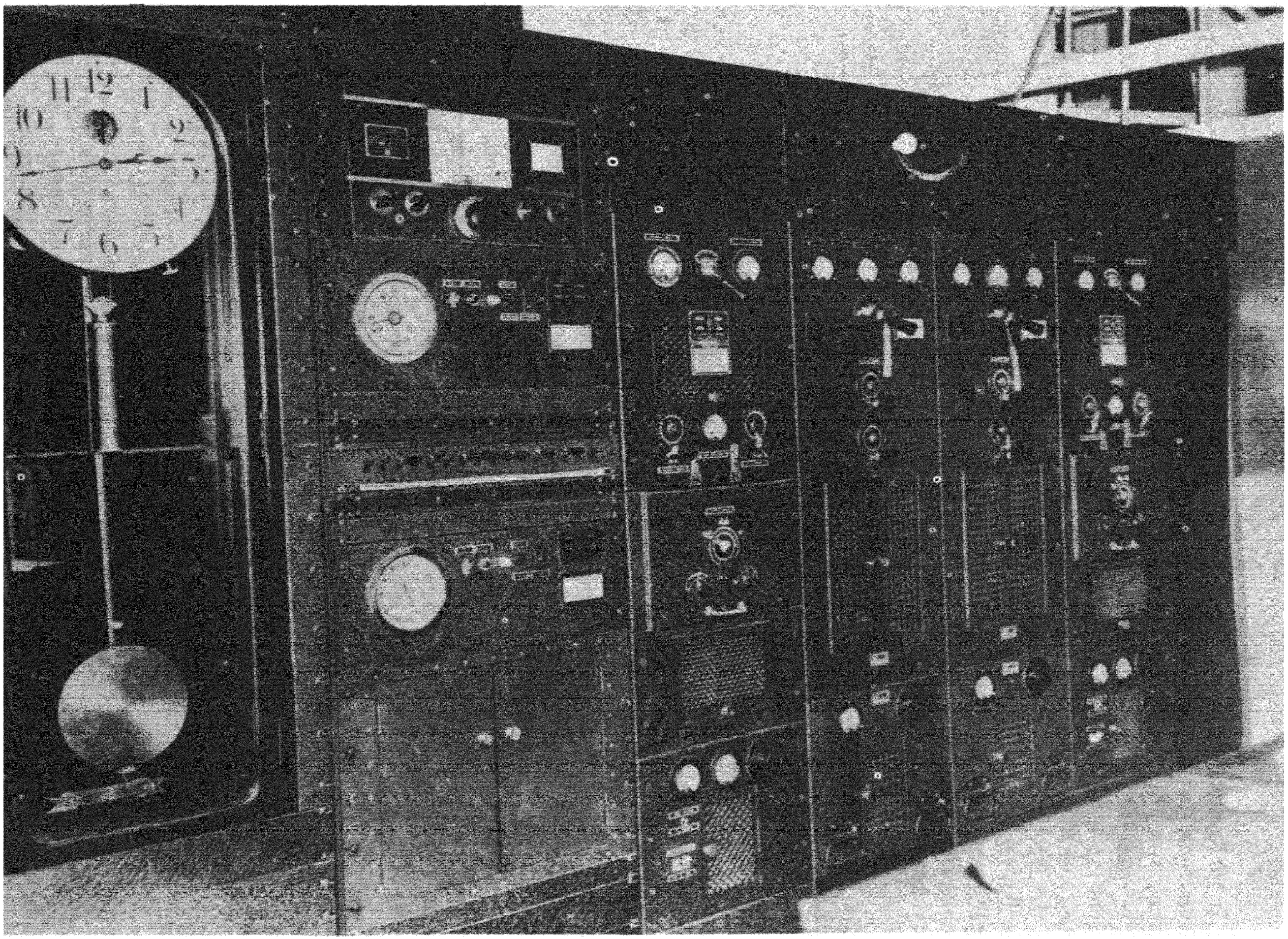


Figure 2-9. — The lineup of equipment at the class A radiobeacon at Cape Henry Light Station, Virginia. One of the primary clocks is shown at the left.

been constructed so as to be capable of taking bearings on either type of signals.

TONE

The greatest portion of United States radiobeacons have a uniform tone modulation of 1000 cycles per second. In the congested areas of Long Island and Nantucket Sounds it has been found advantageous to vary the tonal characteristic from 1000 cycles to 750, 900, 1030 and 1150 cycles, to further facilitate identification.

DISTANCE FINDING STATIONS

A large number of radiobeacon stations are now equipped so that a vessel in the vicinity provided with radio may, by a single observation, determine its distance from the station. If the vessel has a radio direction finder and takes a radio bearing at the same time, its position is at once determined by the distance and the bearing. Without the radio bearing, the distance observation locates the vessel somewhere on a circle of that radius from the radiobeacon. As the method is dependent on the hearing of a sound-in-air signal, it is subject to the same uncertainities as affect such fog signals, and the distance to which it may be used is limited by the range of audibility of the sound signal.

The signals consist of blasts from a sound-producing device (fog signal) synchronized with radio-tone signals. Since the radio signals arrive practically instantaneously (speed 186,000 mi./sec.), the later arrival of the sound signal (speed approximately 1100 ft./sec.) gives an indication of the distance traversed by the latter, therefore of the vessel's distance from the station. At distance finding stations, transmission of the characteristic radiobeacon signal is curtailed 8 seconds before the end of the operating minute, and a one-second dot followed by a five-second dash are transmitted simultaneously with blasts of corresponding lengths from the sound signal device. An observation consists of noting the time difference with reference to any distinctive part of the signals -- for example, the end of the long radio dash and the end of the long sound blast. Dividing the time in seconds by 5.5 gives the distance in nautical miles with an error which should not exceed $\pm$ 10%. The distance finding signals are transmitted only in thick or foggy weather when the fog signal is operating.

The method is applicable to stations equipped with sound-in-air fog signals capable of being brought to full power of sound

in a very brief time.

All distance finding stations and their method of operation, are shown in Coast Guard Light Lists covering areas where radiobeacons are located.

EQUIPMENT OF A RADIOBEACON STATION

The radiobeacon stations, with only one general exception, are established at existing light stations or on lightships. The general exception to this practice is the radiobeacon buoy, which consists of an automatic radiobeacon transmitter installed on a lighted buoy. These have not as yet been extensively adopted.

The equipment of a radiobeacon station consists of a transmitter, primary clock, signal timer, warning device and accessories. All apparatus, so far as practicable, is installed in duplicate with convenient means for switching from one transmitter, generator, or signal timer, to another in case of trouble, so as to insure continuity of service.

TRANSMITTER.--The transmitter is selected on the basis of output power which, in turn, is dependent on the desired range. Transmitters and power amplifiers are available for 5, 25, 150, 750 and 1500 watts output. The radiobeacon transmitter is in most respects similar to a communications transmitter. The distinctive signal is produced by keying the tone modulated carrier.

MASTER CLOCK.--Two types of primary clocks are employed to exercise control over timed functions at the radiobeacon stations. One is a jewelled, weight-driven, pendulum clock capable of maintaining an accuracy within 2 seconds in 24 hours. These clocks are installed at shore radiobeacons where vibration is not excessive. The second type is a jewelled, temperature-compensated, marine escapement clock which has an accuracy within 5 seconds in 24 hours. This latter type is used at all lightship radiobeacons, and at shore stations where vibration is excessive. The function of either type clock is to make an electrical contact once each minute to furnish correcting impulses to the timer, which, in turn, regulates the functions of the radiobeacon station.

SIGNAL TIMER.--The heart of the control system of the radiobeacon station is the timer mechanism. The timer is a mechanical device having a series of cams accurately rotated with respect to standard time. The cams actuate contacts to which are connected the

various circuits of the radiobeacon and auxiliary equipment, controlling them in desired sequence and at predetermined intervals accurately based on standard time. As stated above, the timer cams are kept in synchronism with standard time by means of the impulses supplied through the clock contacts. The timer controls any or all of the following functions at the radiobeacon station: characteristic code tone, transmitter on and off, clear weather or fog schedule of transmission (one minute on --- two minutes off is the usual program of transmission), engine generator starting, timing of lights, sound fog signals, submarine oscillator signals, warning signals, and radiotelephone schedules.

WARNING DEVICE.--In order to insure reliable service from the radiobeacon, an automatic warning device is used in the station which rings a bell whenever the transmitted signal is interrupted, out of time, or seriously impaired in strength or modulation. Aural reception of the radiobeacon signal is also provided for monitoring purposes. The unit, known as the Radiobeacon Supervisor and Alarm, consists of a radio receiver fed from a short antenna of sufficient length to pick up the radiobeacon signal, a spring-wound clock which drives cam-operated contacts, and various copper-oxide rectifiers, relays, resistors, etc., which serve to operate a spring-wound warning bell under contingencies noted above. A loud speaker and an output meter provide the operator with data on the radiobeacon signal.

ANTENNA.--The transmitting antenna is selected to suit the physical factors of the site, the transmitter power and the desired range. For high power radiobeacons, insulated steel towers are used. Antenna coupling houses fed through concentric cable are used with tower type antennas. For low power or limited range, a vertical wire with "T" flat-top is satisfactory. A good ground is essential for an efficient antenna system, and in some locations where the soil is rocky or sandy, a counterpoise system of radials is employed.

ACCESSORIES.--In addition to the major items described, various accessory and power supply items are required at a radiobeacon station. Accessories include: racks and special panels carrying switches, terminals, cable adaptors, storage lockers and shelves. These items are necessary for the proper installation, inter-connection and switching of the radiobeacon equipment. For 115 volt, d-c radiobeacon station installation, a 54-cell storage battery, two d-c engine generators, and two rotary converters, are required. If 115 volt a-c power is available, the only power equipment needed is an auxiliary 115 volt a-c engine generator. Spare parts, including vacuum tubes, are provided for maintenance purposes.

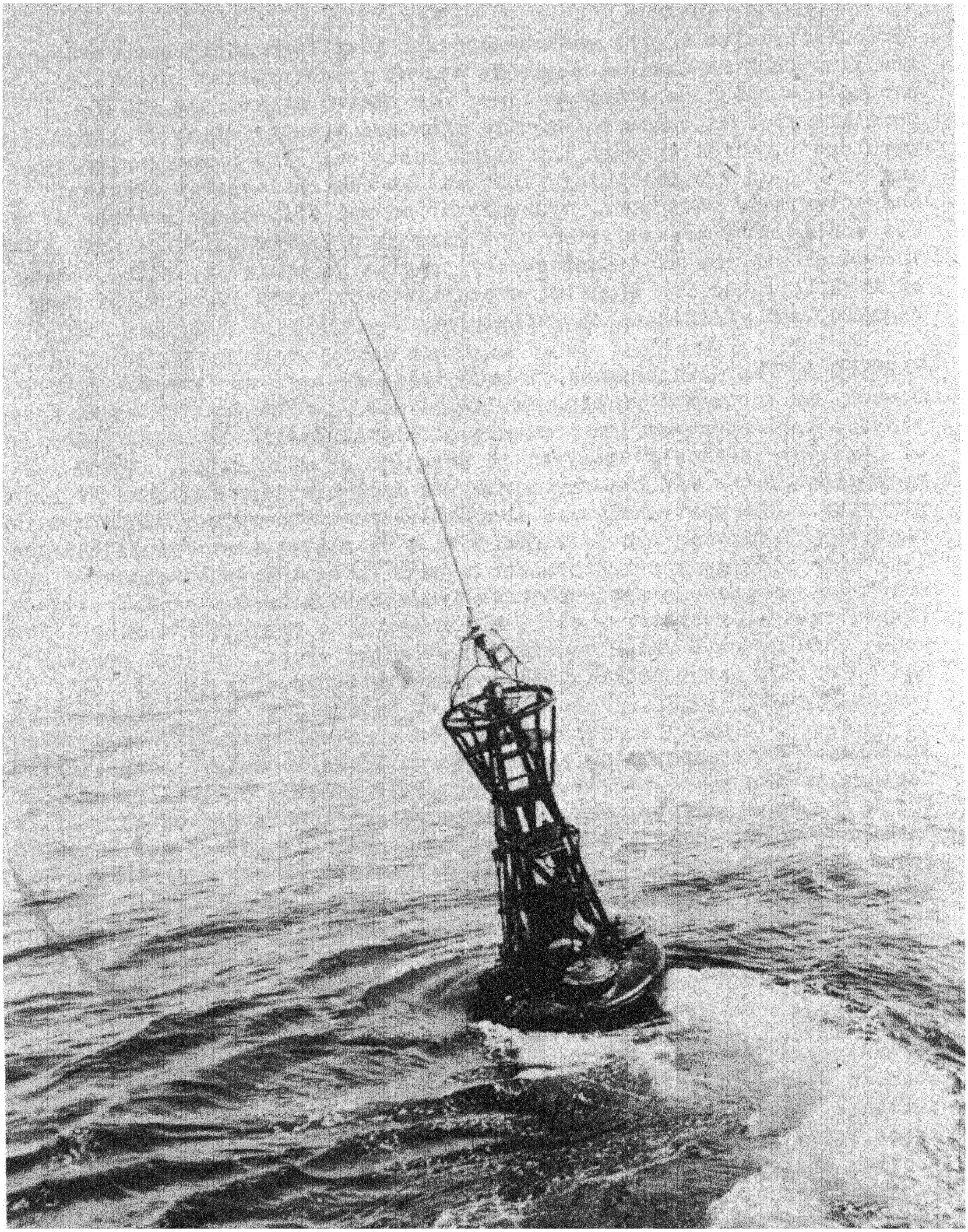


Figure 2-10. -- A typical marker radiobeacon on a lighted buoy.

CLASS D MARKER RADIOBEACONS ON LIGHTED BUOYS

Since there are many harbor entrances and channels where careful approach is required, the United States Coast Guard has for several years been investigating the feasibility of using small, automatic, battery operated Class D radiobeacons located on buoys, often designated as marker radiobeacons. (See Fig. 2-10). These marker radiobeacons are not intended for long range, accurate bearings, but serve rather as local markers on which a pointer bearing can be taken in the same way a navigator takes a bearing on a buoy light. In order to obtain maximum reliability, the buoy radiobeacon transmitter consists of dual crystal controlled oscillators and power amplifier tube channels feeding into a common power amplifier tank circuit which terminates in a single fixed coupling coil. The buoy transmitters are keyed alternately and one of the standard radiobeacon characteristics used is as follows: Two groups of 10 quarter-second dashes with a 1¼-second silent interval between groups for 15¼ seconds with a silent period of 14 3/4 seconds. In case of failure of one of the transmitters, the program consists of quarter-second dashes for 7 seconds, silent 23 seconds. As these marker radiobeacons on buoys cannot at present be synchronized with other radiobeacons, the problem of interference is increased with their establishment.

The average range for a Class D marker radiobeacon as used on lighted buoys, is 10 nautical miles, and there are, at the present writing, 2 such type radiobeacons in actual operation. Both are located on the Great Lakes.

RADIO DIRECTION FINDERS FOR SHIP USE, AS DEVELOPED IN THE UNITED STATES

The radio direction finder is an instrument for observing, by means of radio, the direction of a station sending radio signals. Briefly, in navigation, it is an instrument for taking radio bearings. As generally used in marine navigation in the United States, it consists of a loop antenna mounted above the ship's pilot house, with its axis extending downward into the pilot house, and carrying a handwheel and reference wires or lines over a magnetic compass, dumb compass, or gyro repeater, in the pilot house. (See Fig's 2-5 and 2-11). This loop can be rotated by the navigator or observer, swinging the reference wires over the compass. The loop is connected to a radio receiver in the pilot house. Using this receiver, the navigator picks up the desired station, then revolves the loop and notes the varying strength of the signal until a point is reached where the signal is lost

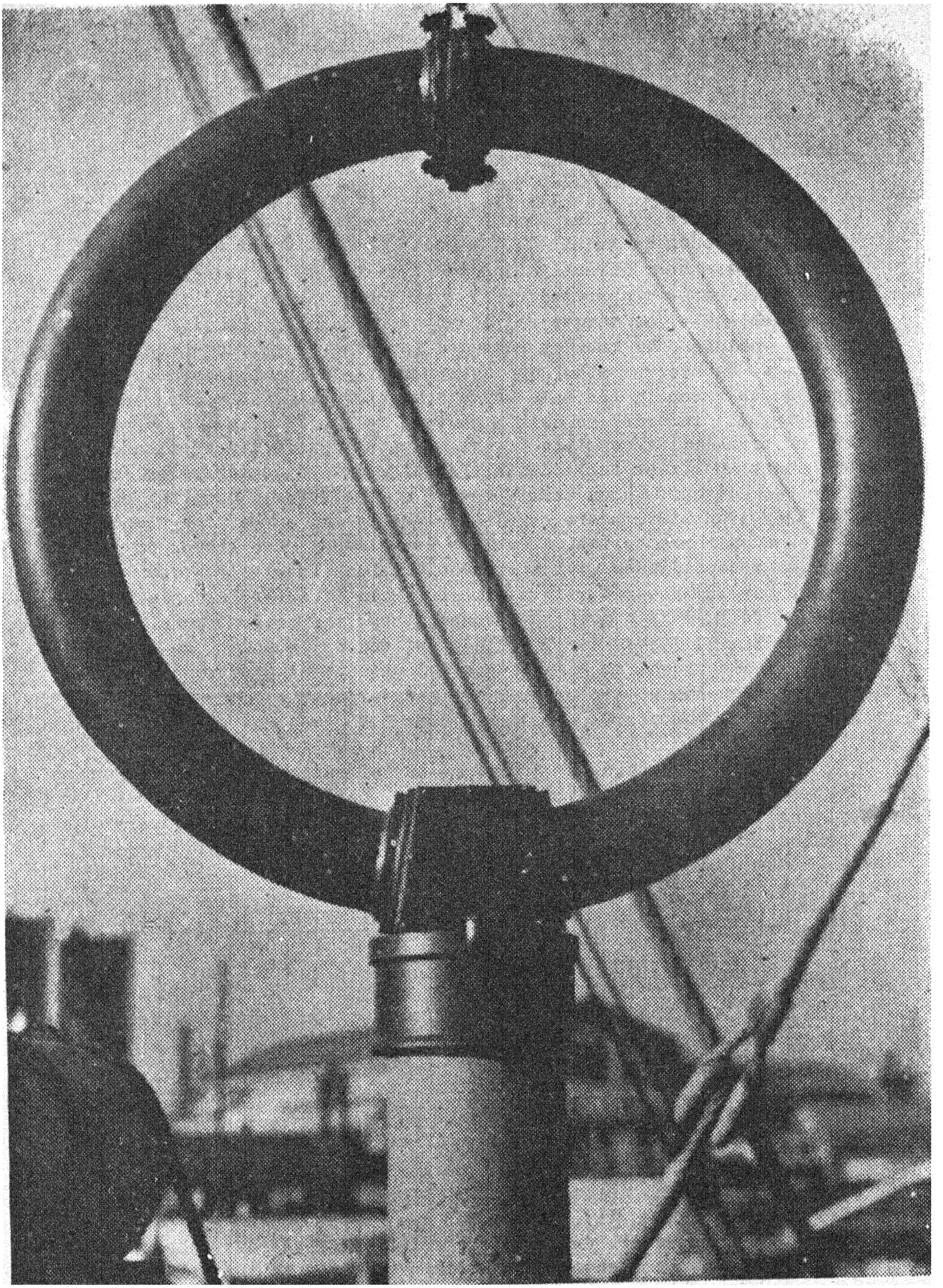


Figure 2-11. -- Weather-proof housing of a modern radio direction finder loop antenna mounted abovedeck.

entirely or nearly lost. This is called observing the minimum. At this point the plane of the loop is perpendicular to a line connecting the ship and the station heard, and the reference wires are so placed with respect to the loop that they then point directly to the station. By carrying the direction from the wires to the compass beneath, or by other simple means, the ship's officer is able to read the direction of the station. Such radio bearings may then be used in navigation on the same general principles as sight bearings are used.

In a well-designed and adjusted radio direction finder, the point of minimum, or no signal heard, is sharp, and bearings may be taken with an accuracy of 1 or 2 degrees. Even when the minimum is not well defined, a fairly accurate bearing may be obtained by swinging the loop to each side, until the signal becomes just audible, and taking the mean of the readings in these two positions.

The method of radio direction finding is based on the directive properties of the so-called coil antenna when used for the reception of radio signals. The radio direction finder includes a coil antenna, and operates on the principle that the amount of electromotive force induced in the vertical loop of wire by an arriving electromagnetic wave depends on the angle between the plane of the loop and the wave front. When the plane of the coil is parallel to the direction of the sending station, the intensity of the signal will be a maximum. As the coil is rotated, the intensity of the signal diminishes until a minimum is reached when the plane of the coil comes to a position at right angles to the line of direction of the signal. The directional characteristic of a coil antenna is illustrated by the diagram in Figure 2-12 where the distance from the center of the coil to any point in the circumference of the circles is proportional to the strength of the signal from a direction passing through that point.

As the diagram indicates, the minimum is well-defined, and the maximum is not; that is, the strength of the signal varies rapidly with movement of the coil near the minimum, but varies slowly with movement near the maximum. For this reason, the minimum is used in observing bearings. Otherwise there would be important advantages in taking bearings on the maximum, in the way of greater audibility and of thus diminishing the effect of interference.

In a rotatable coil of practicable size the voltage induced by a radio signal is very small. For the employment of such small coils for radio direction finding purposes it is essential that there be great amplification.

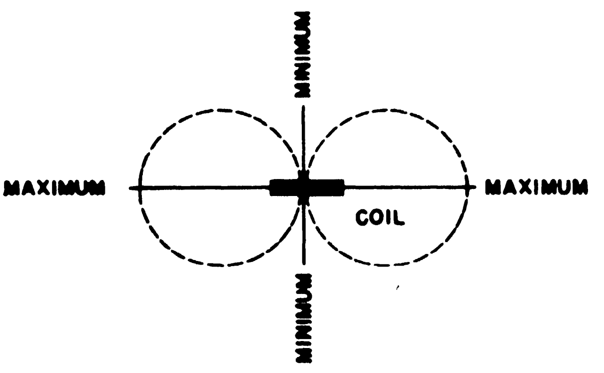


FIGURE 2-12. ILLUSTRATING THE DIRECTIONAL CHARACTERISTIC OF A COIL ANTENNA.

The radio direction finder should preferably be installed in a position easily accessible to the ship's navigator. The navigator desiring to take a radio bearing simply closes a switch, adjusts a single tuning capacitor until characteristic signal of the desired radiobeacon is heard, and rotates the radio direction finder loop until the sound becomes a minimum or is inaudible, and then reads the radio bearing. No knowledge of radiotelegraphy is necessary on the part of the navigator.

It is especially important that a radio direction finder should have good selectivity, so as to be able to eliminate interference from other radio signals on other frequencies when taking a bearing. For the usual needs of navigation it is not essential that it be capable of taking radio bearings from great distances.

There are several other types of radio direction finders in other countries, the most widely used of which is the fixed-loop (Bellini-Tosi) direction finder, which employs a small rotatable search coil. All radio direction finders, however, operate on the same basic principles.

CONTINUOUS CARRIER RADIOBEACONS FOR AUTOMATIC RADIO DIRECTION FINDER USE

In addition to the manually operated types, there have been developed and placed into use radio direction finders with automatic operating features. These devices, when manually tuned to the desired station, will rapidly and automatically indicate the bearing of that station. Automatic radio direction finders (ADF's) are probably used to the greatest extent by aircraft, since time is an important factor in that method of transportation due to the relatively high speed of travel. However, these features have appeal to maritime users, and many ADF's have been installed on shipboard. Marine radiobeacons have for some years been little used by owners of ADF's, because interruption of the carrier by the keyed characteristics would cause the indicating needle to fluctuate rapidly. ADF's have been successfully designed for aircraft use which will operate properly on ordinary radiobeacon signals, but there is no marine ADF yet on the market which will do so.

Experiments were recently undertaken by the Coast Guard to determine the modifications necessary to existing radiobeacons so that the service might be used by ADF equipment having the above described limitations. Results indicated feasibility of

changing the method of transmission during the first minute of the three minute cycle, in such fashion that a continuous carrier exists for the entire minute, and to which the keyed characteristic is applied as modulation. The experimental findings have been carried into practice in the case of 10 radiobeacon stations at the present writing. In addition, in cases where this modification to equipment has been made, the operating schedule has been changed to continuous operation, regardless of the condition of the weather. The extent of additional conversions to this type of operation is influenced by two principal factors, i.e., the extent of interference and the degree of demand. The use of non-automatic radio direction finders is not affected, except that the time of availability of the service is increased.

SOME FACTUAL COMMENTS BY USERS

The following are a few quotations taken from maritime publications, and voluntary opinions expressed in letters from maritime interests:

- - - - - -

"The Radio Direction Finder is certainly the most valuable aid to navigation since the invention of the compass."

- - - - - -

"*permit me to advise that I have received numerous and very favorable reports concerning the synchronization of sound and radio fog signals. Personally, I feel that this is one of the major improvements which has been inaugurated**"

- - - - - -

"The great development of the direction finder which enabled a ship to grope its way in fog and the gradual increase in the numbers of wireless beacons on shore had further added to safety."

- - - - - -

"The modern radiocompass or radio direction finder has, in fact, become one of the most precise navigational instruments now available to those whose everyday business takes them to sea"

- - - - - -

"During our last two voyages we have had very satisfactory results from this particular radiobeacon and have found it very useful when making Boston in foggy weather. I personally obtained a bearing on this beacon at a distance of 200 miles, and the signals were very clear and distinct."

- - - - - -

"It is evident that the underwriters must place great importance on the use of direction-finding apparatus, for it is most unusual for them to allow reduced premiums in respect to any specific aid to navigation, preferring to let such aids win their own reward eventually by reducing claims and consequently premiums."

CHAPTER THREE

RADAR

INTRODUCTION

The Coast Guard by virtue of its close association with the maritime world in performing the functions of saving life and property at sea, and maintaining and operating aids to navigation, is especially interested in the development of radar for use at sea. Long before the secrets of radar were released to the American public, its application as a safety feature on merchant ships had been realized by the Navy and Coast Guard by reason of their use and reliance on this equipment. This remarkable technological achievement, conceived long before the war but brought to practical success only by the impact of war, has already become one of the most important single safety features ever put to use on merchant ships. As time goes by, it can be reasonably expected that radar scopes on the bridges of ships will be as common a sight as the gyro compass.

HISTORICAL BACKGROUND

Radar was born when it occurred to different persons independently and in different parts of the world that the pulse technique could be used to detect and range objects such as aircraft and ships. This idea seems to have occurred almost simultaneously in America, England, France, Germany, and perhaps also in Japan. Scientists in these countries worked secretly on problems of increased power output, shorter pulses, directional antenna systems, and many other practical aspects of the problem.

The basic principle of radar (the name is derived from "Radio Detection and Ranging") is not a difficult one. In 1886 it was proven that radio waves are reflected from solid objects. In 1904, a German engineer was granted a patent in several countries on a proposed way of using this property as an obstacle detector and a navigational aid for ships. A discovery which led to the actual development of radar was made in 1922 by two scientists working at the Naval Aircraft Radio Laboratory, Anacostia, Md. Testing plane-to-ground communications, they noticed that ships moving in the Potomac River distorted the pattern of radio waves, causing a fluctuating signal. From this discovery, development was pursued almost continually after that

until 1935, when Congress provided a $100,000 appropriation to the Naval Research Laboratory for the specific development of radar. A rather crude radar was tested successfully in 1937 aboard the U. S. S. LEARY, and a greatly improved one was given extensive sea trials on the U. S. S. NEW YORK in 1939. Before that, experimental work conducted from the ground employed a variety of ships and aircraft and the dirigible AKRON.

The development of radar moved so rapidly through the last years before the war and the early years of the war itself that only the radar specialist had any real knowledge of its behavior and its capabilities. Yet the immediate demands of war made it necessary to expand suddenly and tremendously in all directions at once.

STUDY OF RADAR BY THE COAST GUARD

As the war progressed and the existence of radar became known publicly, the Coast Guard was approached by commercial ship operators with requests as to how radar could be used for commercial navigation. While the information could not be released under wartime restrictions, the need for such a study was realized and an extensive program to collect data was undertaken. The U. S. C. G. Cutter MACKINAW was radar equipped specifically for study of conditions on the Great Lakes. Additional ships and planes were equipped and specialized personnel assigned for a study of conditions on the Grand Banks during the 1945 Ice Patrol. Various harbor craft were equipped and studies on the employment of radar in harbors were made. To coordinate activities a radar study group whose sole purpose was to disseminate existing information and accumulate new data was established at Coast Guard Headquarters in the early part of 1945. The employment of radar as a collision prevention device and as an aid to navigation was evident immediately.

The Coast Guard has determined a set of recommended minimum specifications for radar installation aboard merchant vessels that has served as a mutual starting point and impetus for future study and development of this equipment to further ensure the safety of lives and property at sea. Realizing its possible use in conjunction with other electronic aids to navigation, the Coast Guard felt that favorable consideration should be given to arriving at uniformity of design and standardization and that every effort should be made to provide simplicity of operation with optimum performance. The problem, however, is broad in its scope because of the varying operational requirements of the ship operators and the expense involved.

In carrying on this work consideration was given to the experience and knowledge gained during the war, to the employment of a merchant marine radar with present and contemplated navigational aids, and to the possible future effect that such installations would have on the revision of present navigational laws and possible reduction of insurance rates. As a result, three sets of minimum specifications were prepared by the Coast Guard, with the cooperation and assistance of the Navy Department and Radiation Laboratory. The specifications were submitted at a conference of radar manufacturers and representatives of the maritime industry as a basis of discussion. As a result of this meeting a new and more complete set of recommended specifications has been issued.

Nothing in the revised specifications is to be considered as a limitation upon the number of improvements or innovations which may become desirable as the art of microwave detection and navigation is developed. As in the past, the Coast Guard will revise these suggested specifications to reflect additional knowledge acquired through investigations of new equipment, contact with engineering representatives of manufacturers, contact with shipping interests and conferences with developmental agencies and interested nations. The specifications are purely recommendatory in nature and have no administrative statutory relationships to other merchant vessel equipment required by the Coast Guard. They are promulgated in the public interest and serve only to further that interest.

The Advisory Minimum Specification Briefs are to be found in the appendix.

MILITARY vs COMMERCIAL REQUIREMENTS

Since radar was developed for purposes of detecting and ranging in warfare, many features of wartime radar were not suitable for direct application to commercial types. Some of the differences in requirements for the two purposes are discussed in the following paragraphs.

In the case of wartime radar it was necessary that the enemy be detected at great distances, hence the radar sets were very powerful. Commercial shipping has no such requirement and consequently sets need not have such great range and power.

The initial cost of equipment and cost of operation was

secondary in wartime, but is very important to the commercial operator. The armed forces had trained crews whose only job was to operate and service the radar. The commercial radar, however, must be designed for easy operation by personnel with little or no training.

The above considerations have demanded and allowed simplification in the commercial radar sets. A compromise, however, between simplification and operational capabilities must be made.

Space limitation is another important factor that has dictated to some extent the design of commercial radar. While the armed forces had entire rooms devoted to radar equipment, the commercial radar must have its various components such that they can be placed where space and convenience will allow, the only requirement being that the indicator be in the wheelhouse.

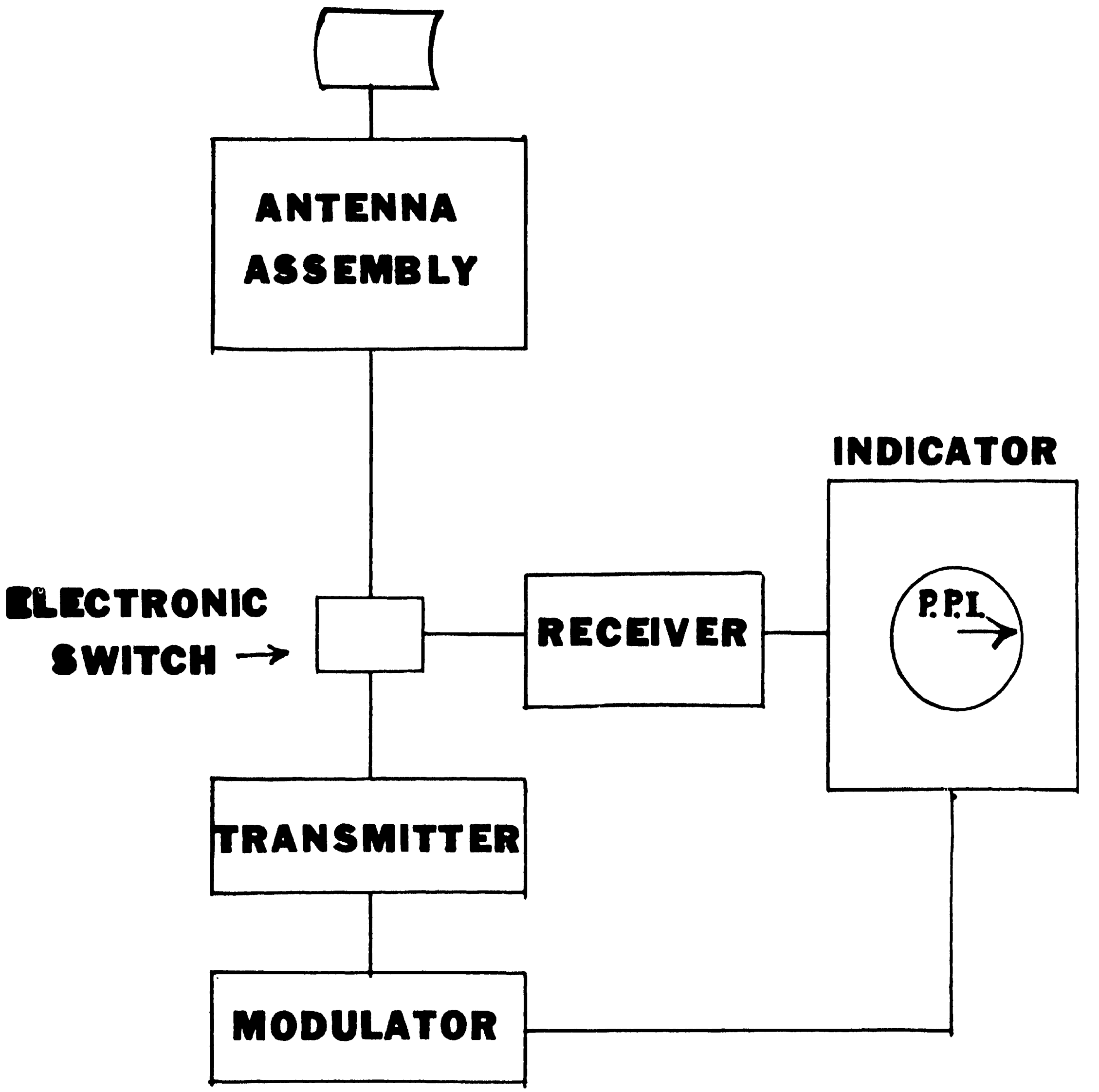
BRIEF DESCRIPTION OF RADAR COMPONENTS

Basically radar employs very short electromagnetic waves and utilizes the principle that these waves can be beamed, that they travel at a definite speed in a straight line and they will be reflected from any discontinuity in the medium through which they are transmitted.

The typical surface radar consists of five components, the transmitter, modulator, antenna, receiver, and indicator. In addition to these components, power supply is an important factor to be considered in determining the actual characteristics of any radar set. While the physical form of each of these parts may vary widely from one type to another, all radars contain them. Figure 3-1 illustrates the arrangement of the fundamental components in a block diagram.

The transmitter consists of the radio frequency oscillator which produces the electromagnetic waves of energy. Because of the necessity for beaming this energy, while at the same time being able to receive suitable echoes, the oscillator generates very high-frequency energy. The development of a suitable oscillator with sufficient power has been one of the major accomplishments of the radar technicians.

In order that range may be determined accurately, electromagnetic waves are emitted in the form of pulses and each pulse is transmitted for a very short period of time, one-millionth of a second (1 microsecond) or less. After each pulse the transmitter is silent while echoes from that emitted pulse are being



Block Diagram of Radar

Fig. 3-1.

received. The procedure is then repeated about one thousand times a second. The modulator, or keyer, is the unit which turns the transmitter on and off and forms these pulses.

The antenna assembly is so designed as to beam the energy at the target, normally being accomplished by the use of an antenna and reflector in much the same manner that the headlights of an automobile are directed. The echo is received back through the same antenna and directed to the receiver. The antenna must be directional and concentrate the radio energy into a well-defined beam, since this is the method by which the direction of the detected objects is determined. It must also be capable of being rotated or trained in order that the surrounding area can be properly scanned.

In the receiver, which employs the superheterodyne principle, the radio energy reflected back from the target is converted into a form that may be presented visually on an indicator or scope. Since a very small amount of power is reflected by an object the receiver must amplify it many times. Because the same antenna is used for outgoing and incoming signals a method of disconnecting the receiver from the antenna is needed during intervals when the transmitter is operating. Due to the rapid switching that is necessary, an electronic switch is used.

It is the indicator of a radar that presents the information collected in the form best adapted to efficient use of the equipment. The indicator commonly used in navigation is the plan-position-indicator, commonly abbreviated PPI, which presents on the scope a continuous polar picture of the surrounding area.

RADAR FREQUENCY BANDS

The following bands are now provided in the United States for merchant marine radar and associated beacon:

	Radar	Beacon
10 Centimeter - - - - - - - -	3000 - 3246	3256(mc)
5 Centimeter - - - - - - - -	5460 - 5650	5450(mc)
3 Centimeter - - - - - - - -	9320 - 9500	9310(mc)

The 5 centimeter band has been allocated in order that the opportunity be provided to determine whether radars operating in this band might combine many of the desirable features of those in the other two bands. Equipment operating in the 5 centimeter band is not yet generally available, and no advisory specifications have been prepared for equipment in this band.

PROGRESS TO DATE IN THE COMMERCIAL RADAR FIELD

The advisory specifications have in general been accepted both by radar manufacturers and shipping interests alike. Manufacturers have adhered very closely to them and in many ways have exceeded their requirements, and shipping interests have required that the radar they purchase actually does meet the specifications. In general, therefore, the specifications have more than served the purpose for which they were intended and have been an important factor in the rapid progress that has been made in the manufacture and installation of commercial radar.

Five United States manufacturers now have radar equipment available for sale to the general public. It is impossible to select a certain manufacturer's radar as superior to that of another; selection must be based primarily upon the use to be made of the radar, upon the installation problem in the case of a particular vessel to be equipped, and upon the particular tastes of the user. The various aspects of the problem of selecting and installing a merchant marine radar are discussed in some detail later.

There are over 100 commercial type radars installed on United States vessels at the present time, and new installations are being made almost every day. Installations have been made on many different types of vessels operating in various waters. It is expected that this program will continue and that an ever-increasing number of ships will be radar-equipped.

Figures 3-2 through 3-14 show various types and views of marine installations and components of equipment. These pictures indicate how some manufacturers have met certain of the problems that have come up with regard to commercial radars. The amount of flexibility to be found in the available commercial radar sets is also illustrated.

People in many fields have shown interest in commercial radar installations and have made visits to or trips on vessels to observe the equipment. Ship owners, captains, pilots, admiralty lawyers - all have an interest in radar.

The Coast Guard, in the course of its study, and in connection with the issuing of the advisory specifications, has

accumulated a considerable amount of information from actual users of the commercial radars. All such testimonials are consistent in that all praise radar. Masters of some vessels have come to rely upon radar to such an extent that they consider it almost essential to navigation and the safe operation of their ships.

Reports from vessels utilizing radar on the Great Lakes have been particularly enlightening. The following are excerpts taken from such a report:

> "....The actual practical operation of the set from the navigator's point of view is quite simple and consists of turning a few knobs on the control panel. Our knowledge of where the various aids to navigation and points of land, etc., should be, is to our advantage in using radar on the Great Lakes. After clearing harbors and rivers, getting into the open lake, the picture broadens and ships and points of land in all directions having a variable distance up to about forty miles are plainly visible.
>
> "The most comforting feeling for a navigator is when he hears a fog whistle ahead and can definitely establish the bearing of the ship sounding this fog whistle. The next step, then, is to change the course accordingly so a safe passing can be accomplished.
>
> "When I had used the set for about one month, I got caught in the Soo River in a dense fog. We were light and proceeding at a moderate speed. ....We navigated from Johnson's Point to the Soo without encountering any difficulty, almost entirely by radar. As we approached the Soo piers, the weather was so thick we could only see about 200 feet. I called the Lock Master by radio telephone and was given the 4th lock, which at that time was the only lock I could use because of boats tied up to the approaches of the other locks.
>
> "After getting up to within one mile of the piers, we recognized clearly their outline, and could see the angle at which we were approaching. This was at 2:00 o'clock in the morning and we did not see the lights on the piers until we were almost abreast. We locked through and proceeded toward Big Point. I might mention

here, we had passed a number of boats anchored in the river. They also showed up on the indicator and we could note very clearly the direction in which they were lying".

Radar has proved to be of great value in saving transit time between ports, since it permits ships to proceed on their way where otherwise they could not do so because of fog or other adverse weather. Such was true in the case of one of the large ocean liners, which was able to proceed into New York harbor during a fog. This of course, resulted in a considerable saving in money and time. For this reason, also, many vessels plying the rivers of the United States have been and are being radar-equipped. Fogs, for example, are especially prevalent in the Ohio Valley in the fall and may reduce visibility to no more than about 25 feet, forcing vessels without radar to tie up for as much as two days at a time to await the lifting of the fog. It has been estimated, in fact, that because of the saving in transit time, ship operators may pay for the radar on a ship in less than a year.

In the past, various marine disasters resulting from poor visibility have resulted in the loss of many human lives, to say nothing of the loss of valuable cargo. More than one such disaster has resulted in the loss of over 1,000 lives.

No one, of course, can say how many collisions have been and will in the future be averted because of the advent of radar. Suffice it to say, however, that radar, when properly used and relied upon, makes collision almost impossible. All available safety precautions must, in fact, be taken to avert collisions during inclement weather. This is borne out by an interesting case recently tried in a Federal court. The court decided that the failure of a vessel equipped with radar and carrying competent operators to use the radar while underway in low visibility was directly contributory to the collision in which the vessel was involved. It was held that the use of radar, where available, was one of the ordinary precautions not to be neglected under the dictates of Article 29 of the Rules of the Road. This was based upon the fact that ample demonstration had been made of the usefulness or availability of radar as an anticollision device.

The value of radar, therefore, as a navigational and anticollision device for commercial use has been definitely established and much progress has been made toward production and installation of the equipment. Not only is radar justifiable from the standpoints of economy and safety of life and property at sea, but its value is such that probably few will find they can afford to be without it.

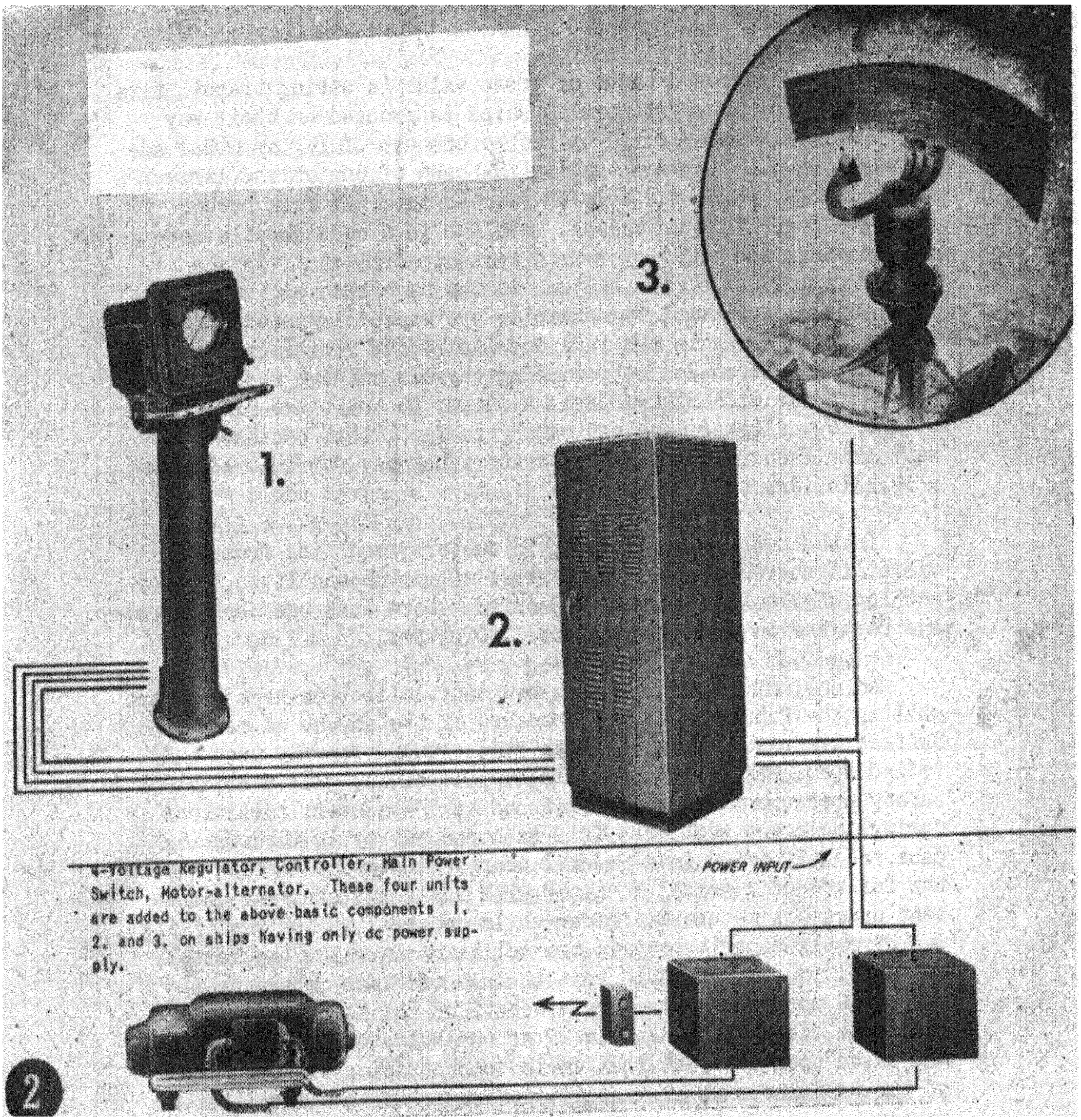


Fig. 3-2. Basic units of one type radar: (1) indicator; (2) transmitter-receiver; (3) antenna. These three units are all that is required on ships with alternating current supply.

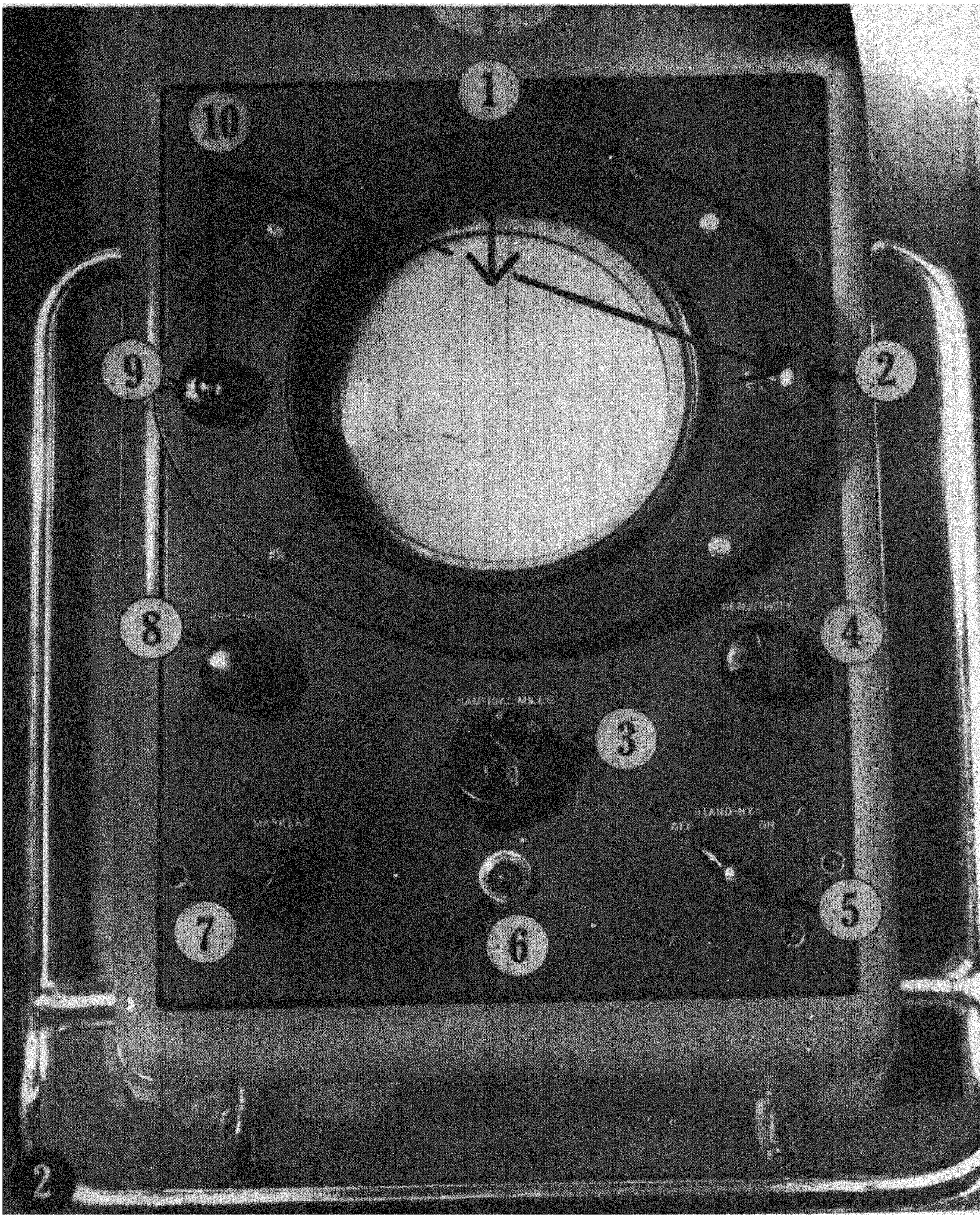


Fig. 3-3. Face of one type indicator showing controls: (1) scope; (2) bearing cursor knob; (3) range selector switch; (4) sensitivity (receiver gain) control; (5) main control switch; (6) indicator light; (7) marker control; (8) brilliance (intensity) control; (9) azimuth scale knob; (10) azimuth scale and bearing cursor light controls.

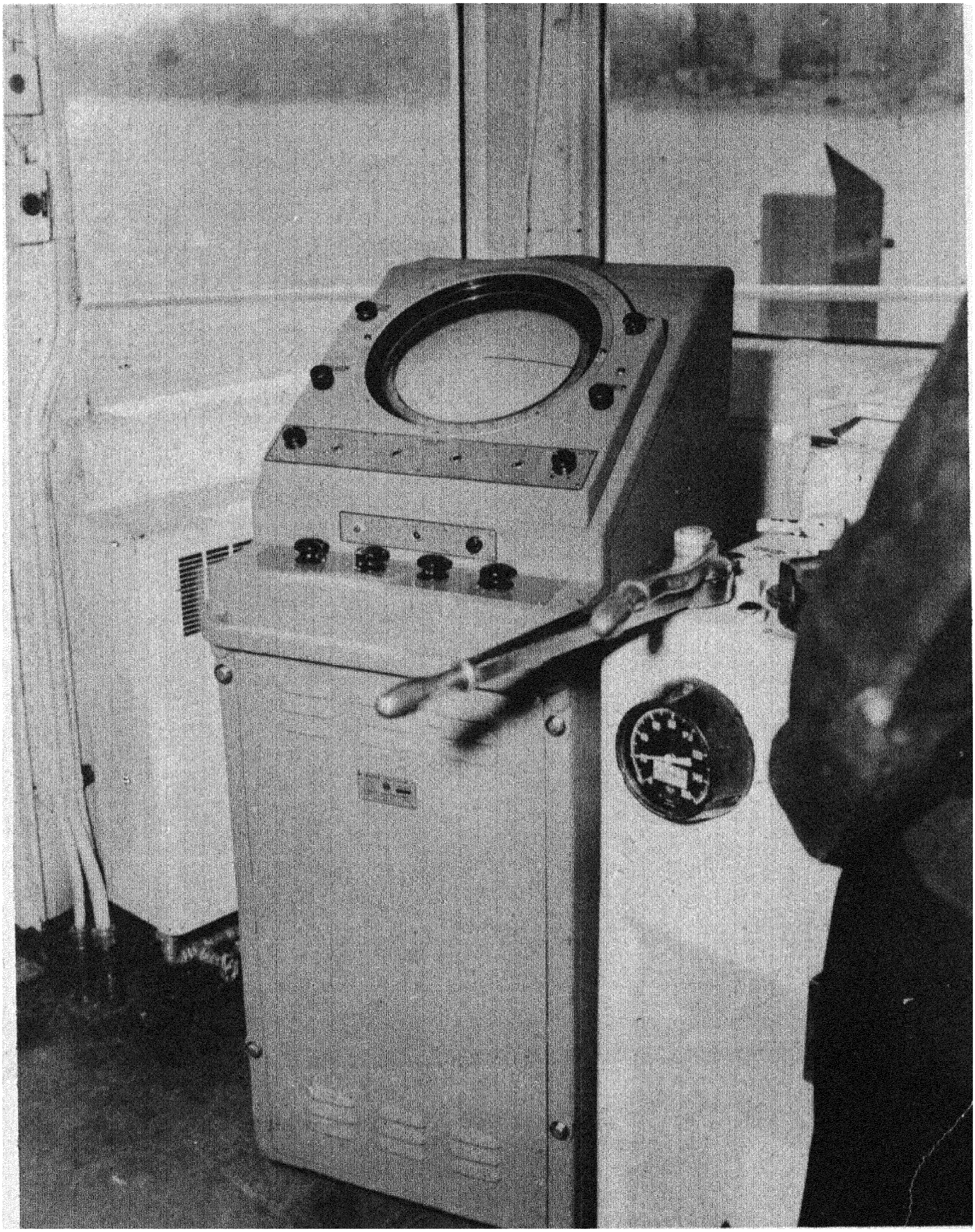


Fig. 3-4. Indicator mounted in the wheelhouse.

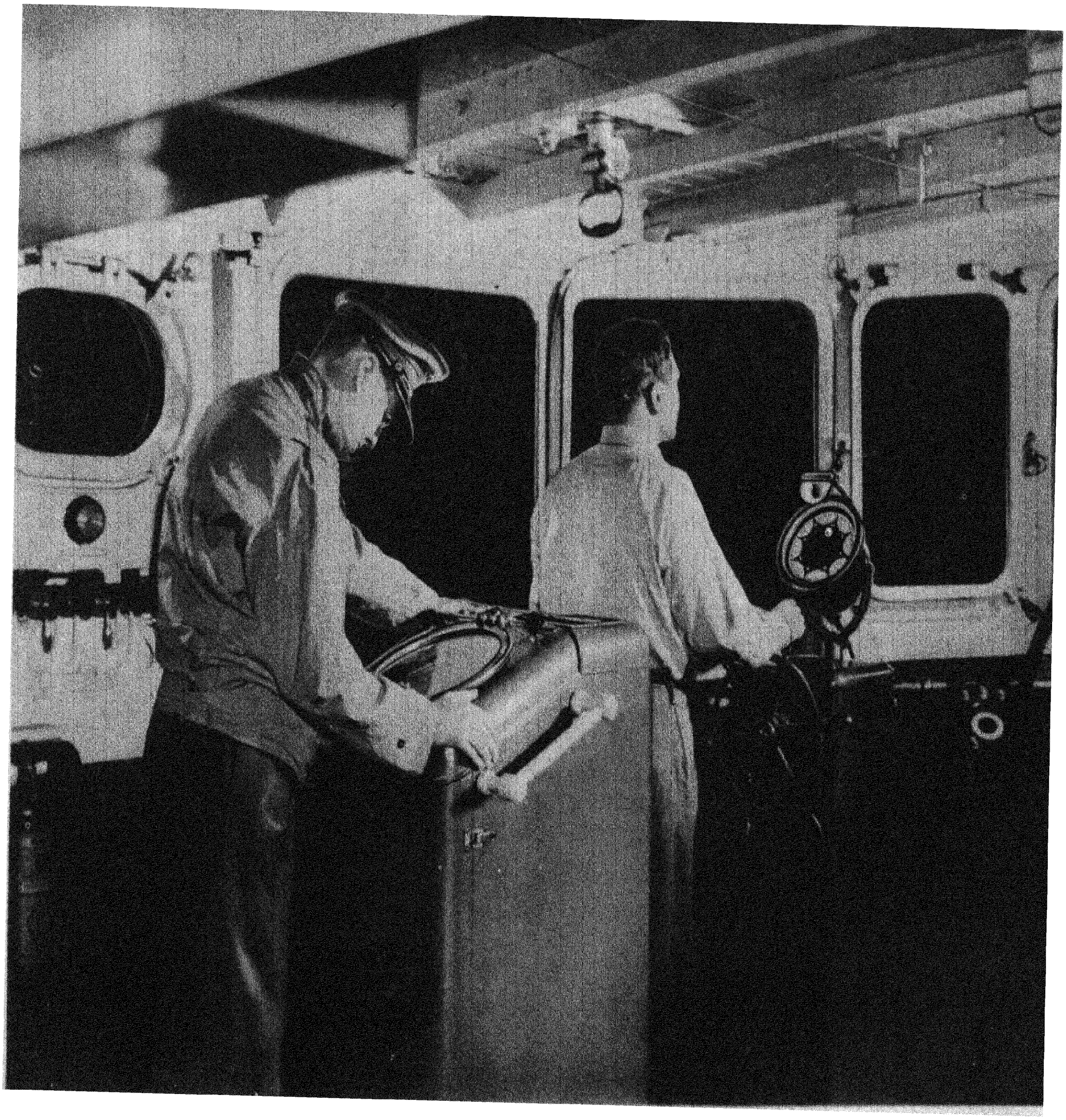


Fig. 3-5. Radar Console.

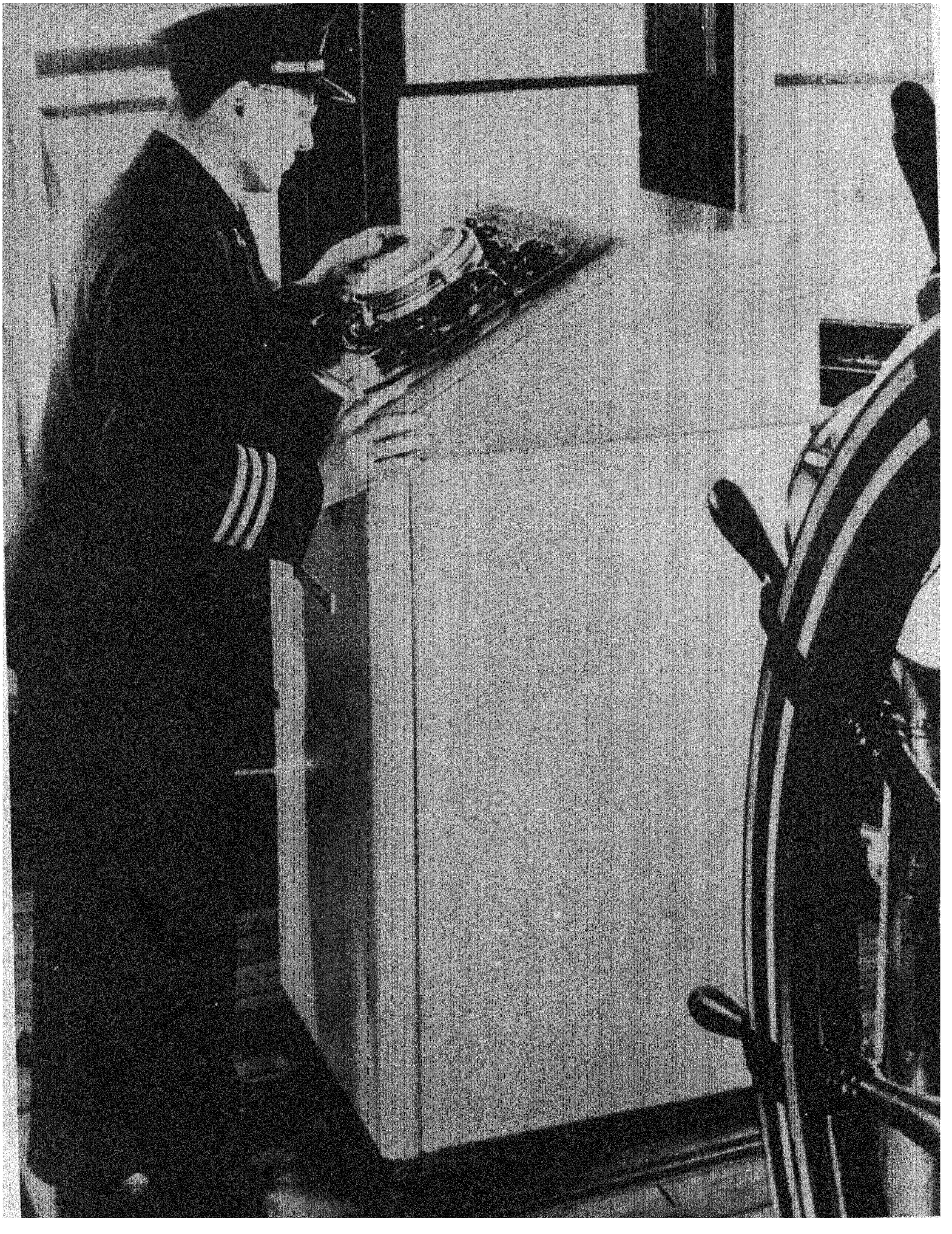


Fig. 3-6. Another type of radar Console.

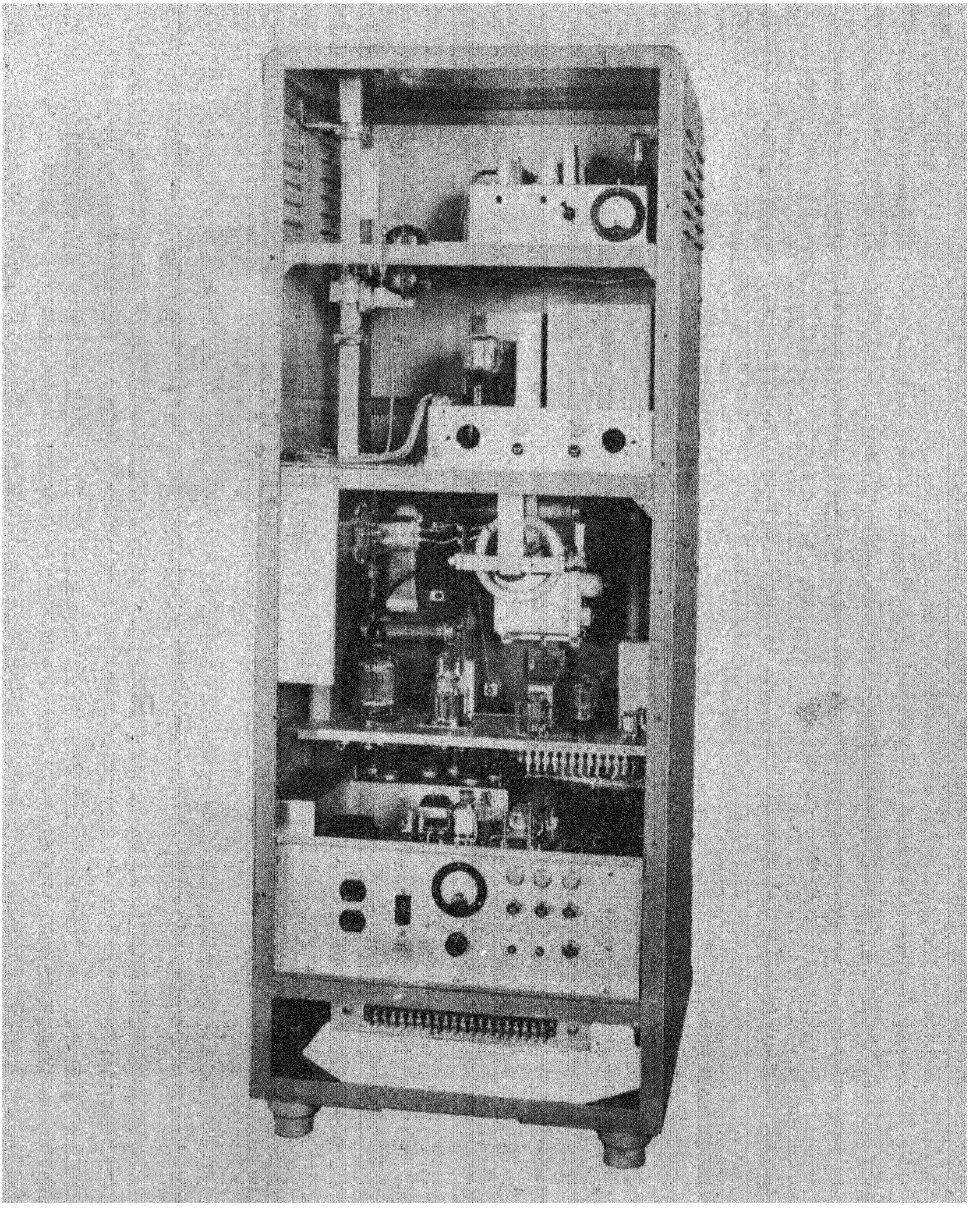


Fig. 3-7. Transmitter-receiver unit (with door removed).

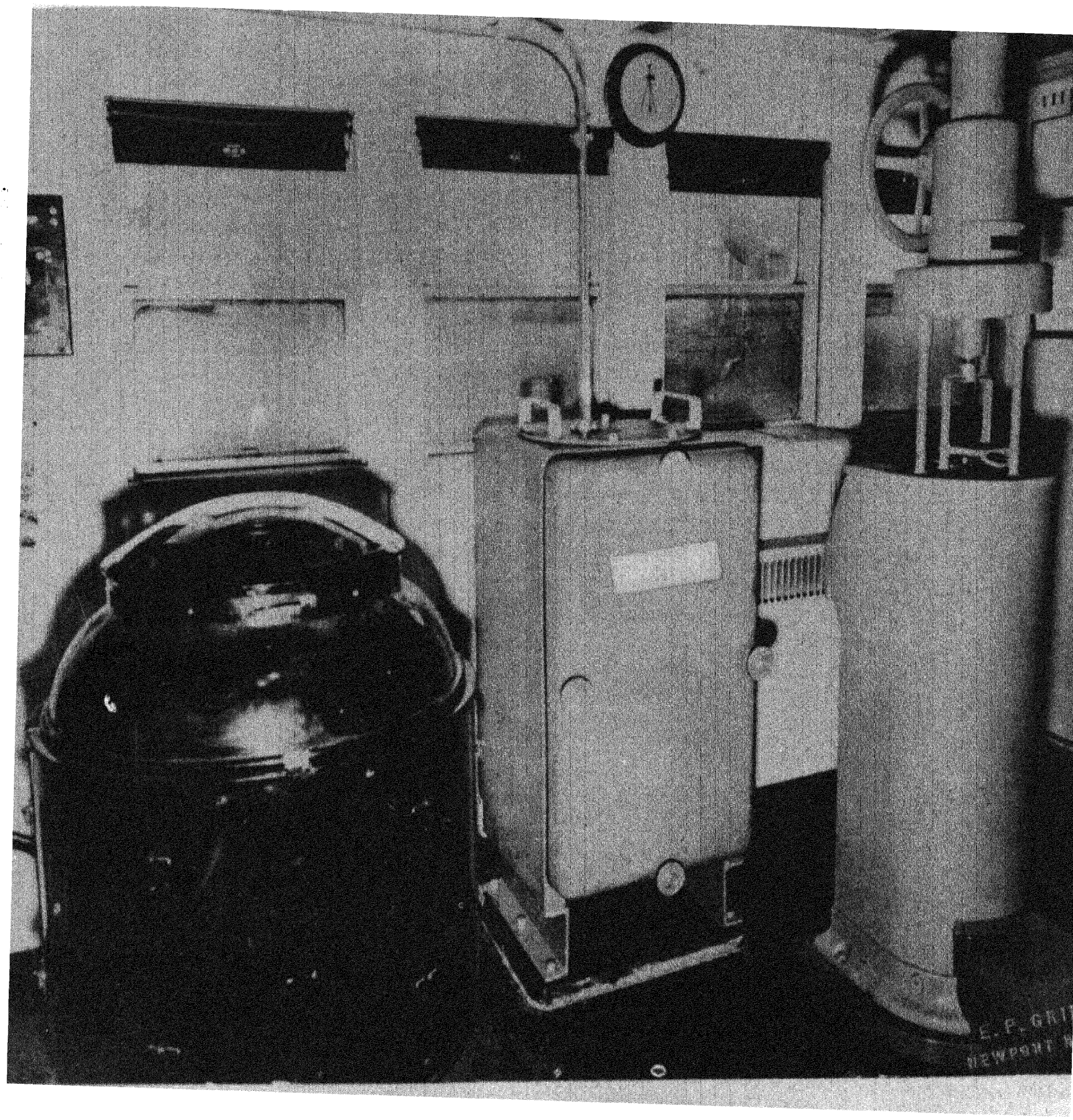


Fig. 3-8. Transmitter unit.

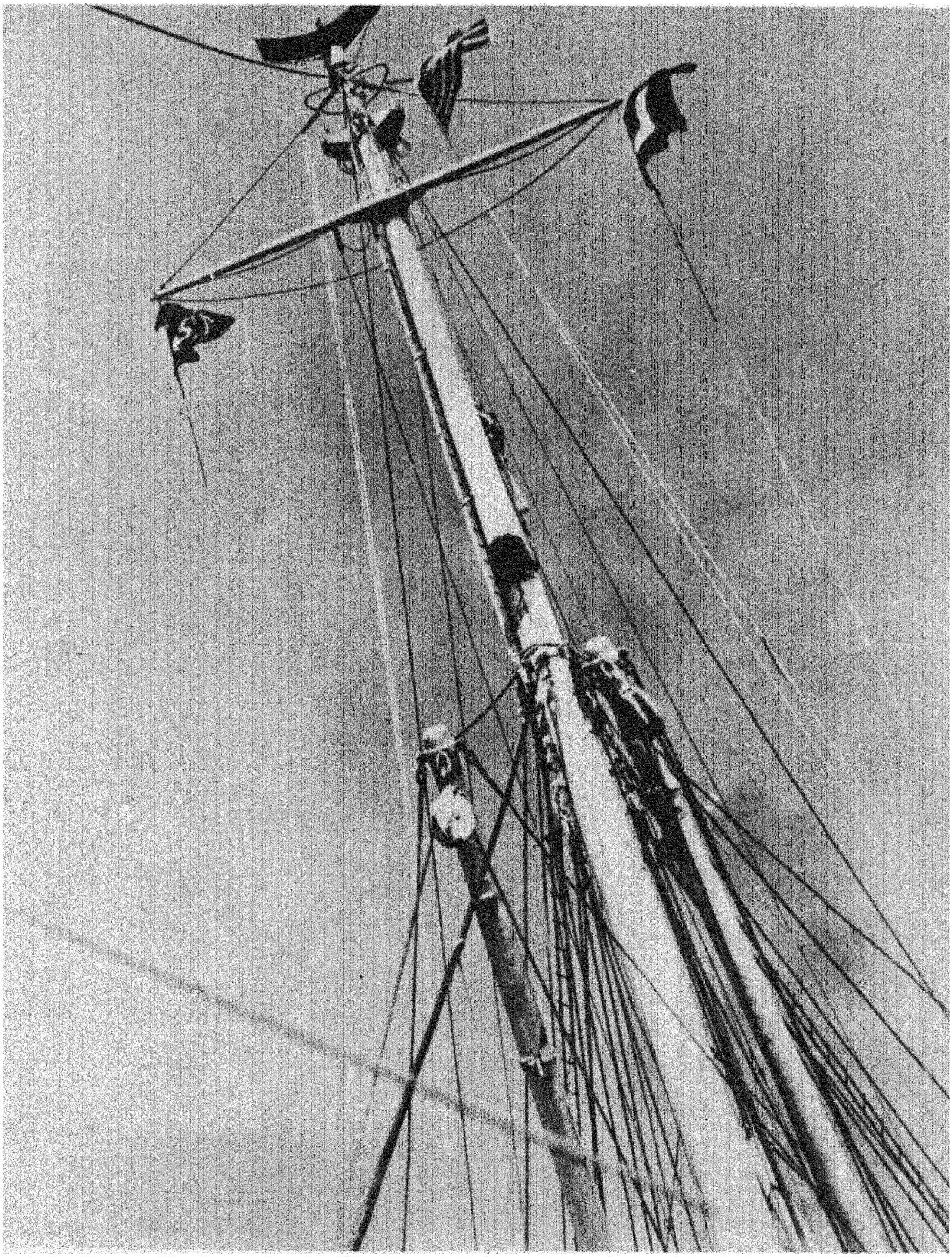


Fig. 3-9. Radar antenna mounted at the top of the mast.

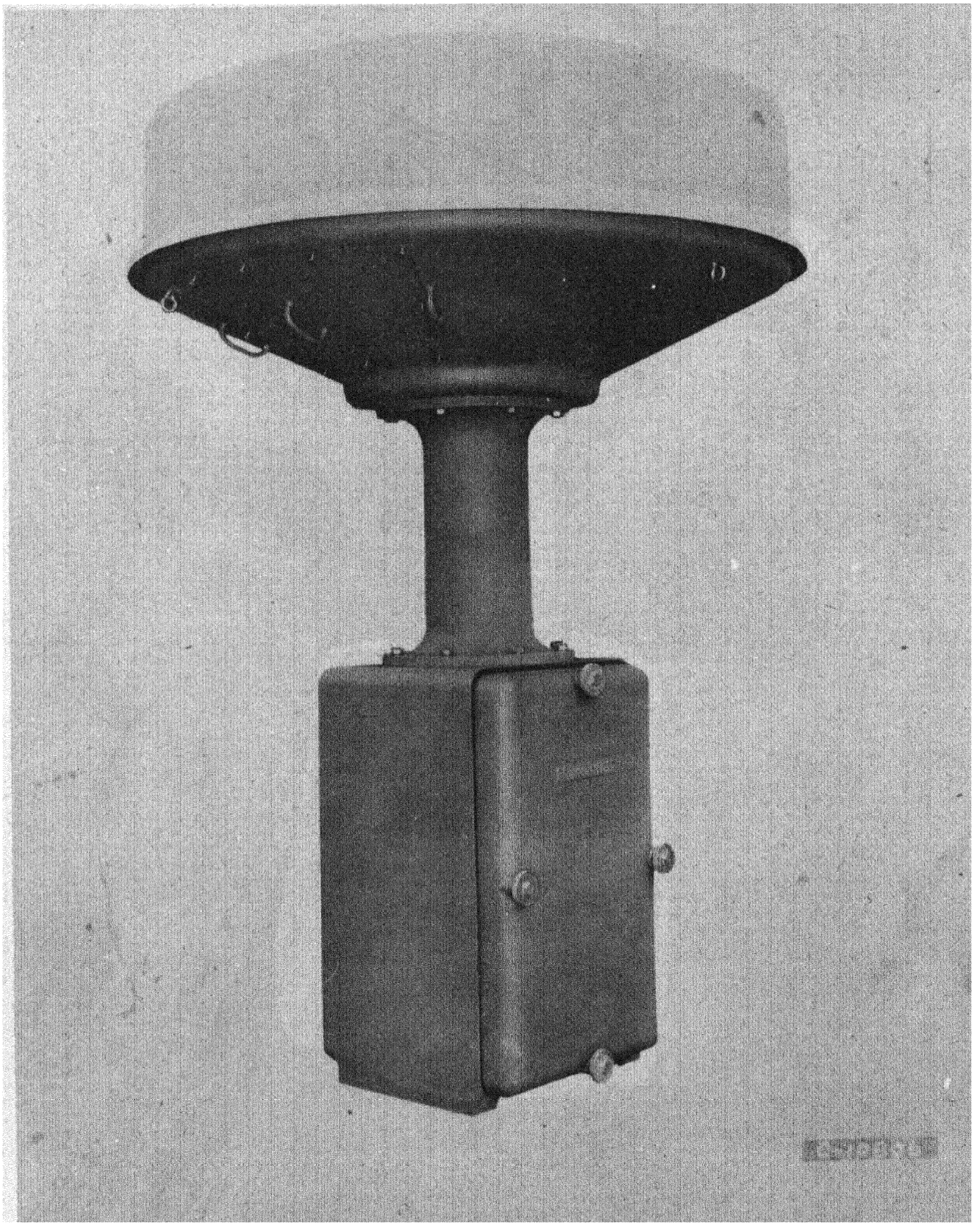


Fig. 3-10. Antenna enclosed in dome.

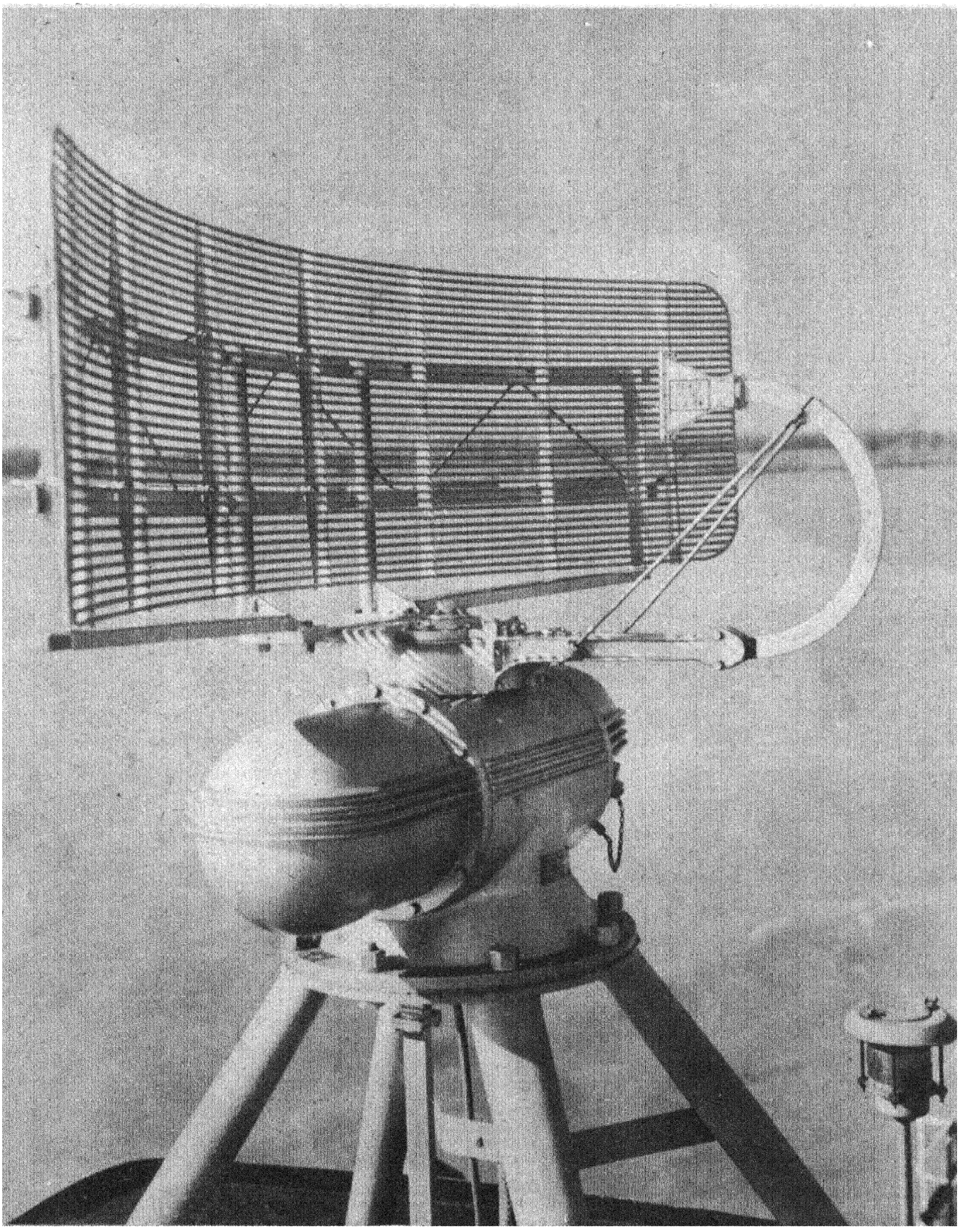


Fig. 3-11. Details of radar antenna as mounted atop the pilot house.

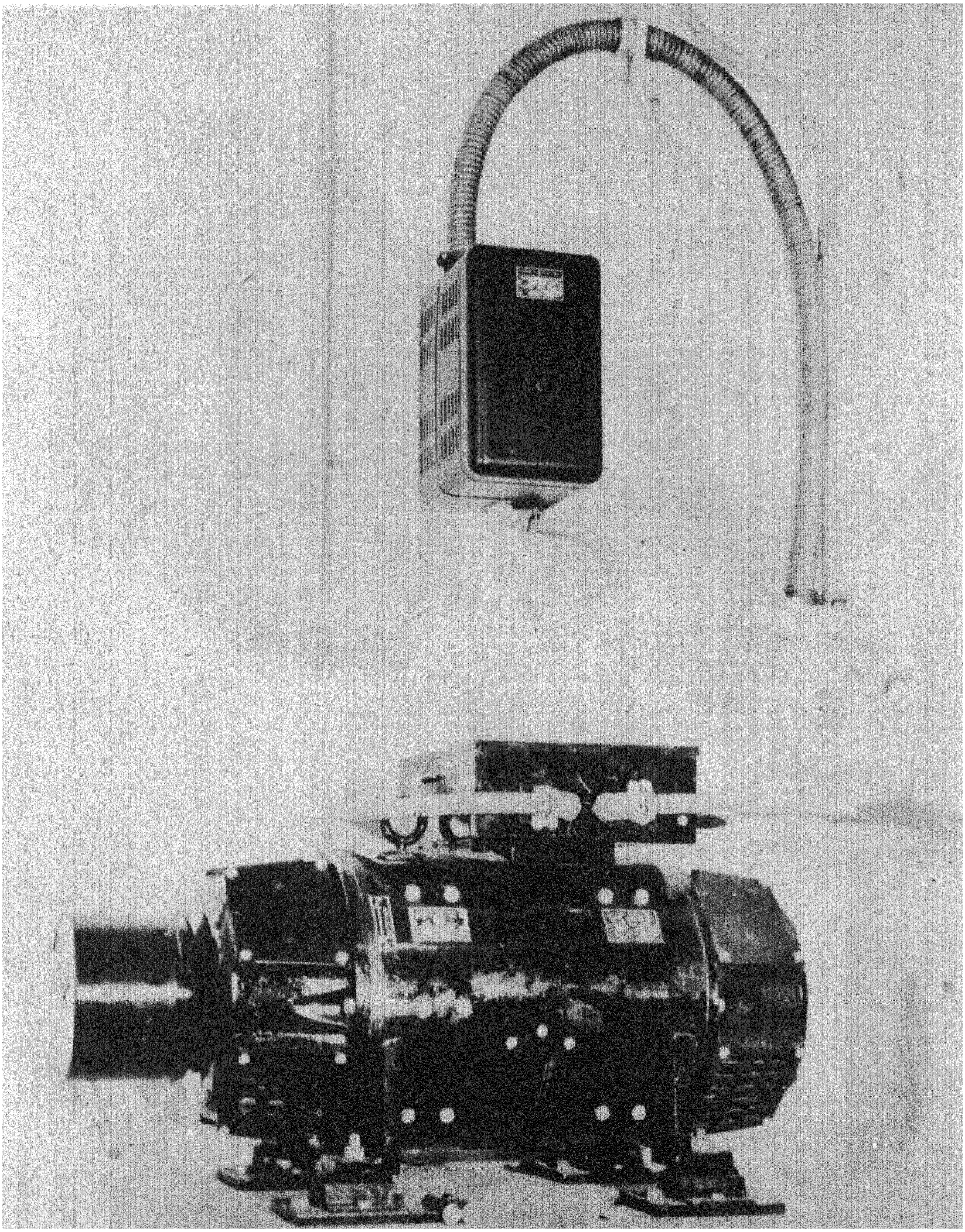


Fig. 3-12. Typical motor generator for use where ship's supply is direct current.

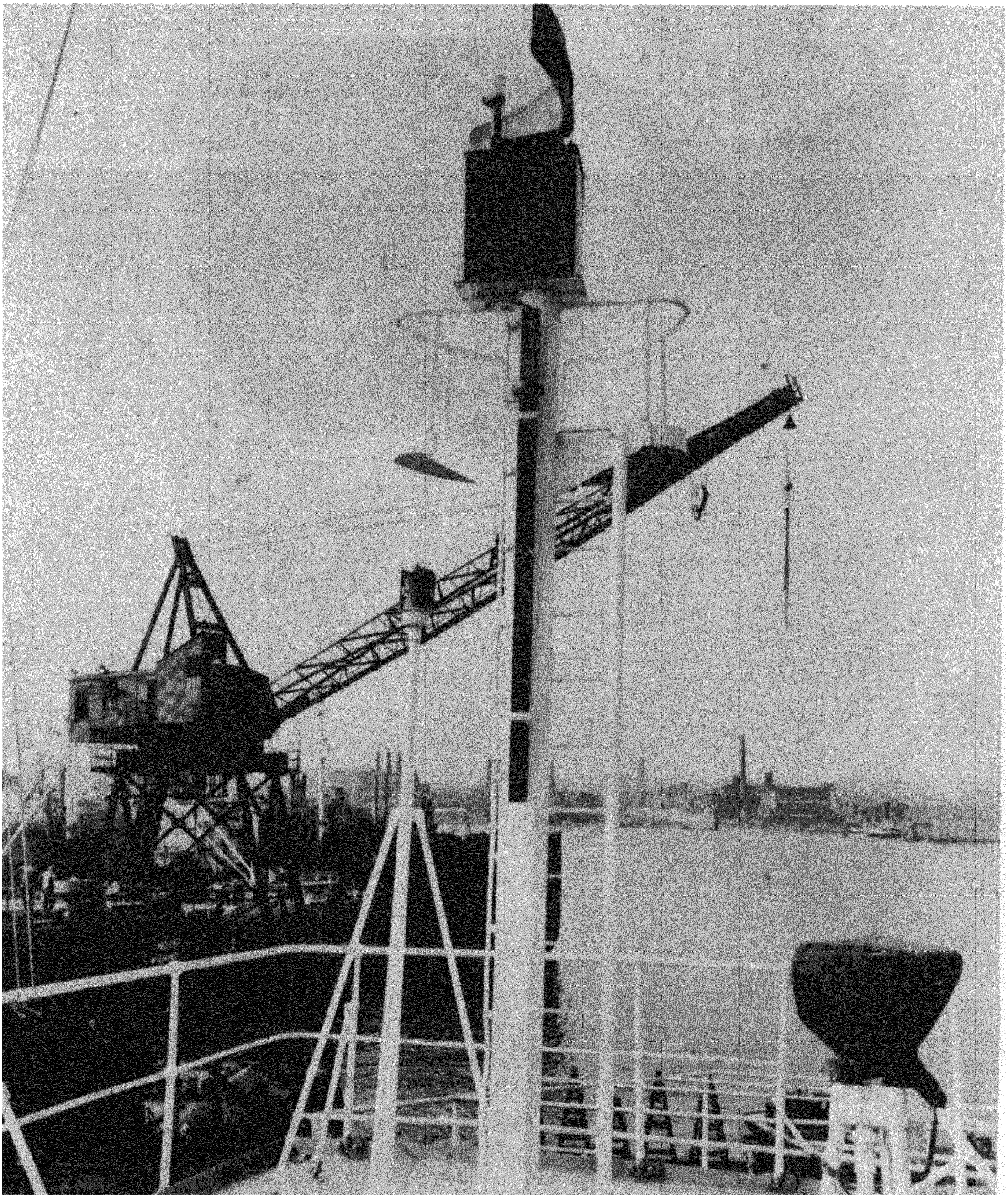


Fig. 3-13. Another type of antenna installation.

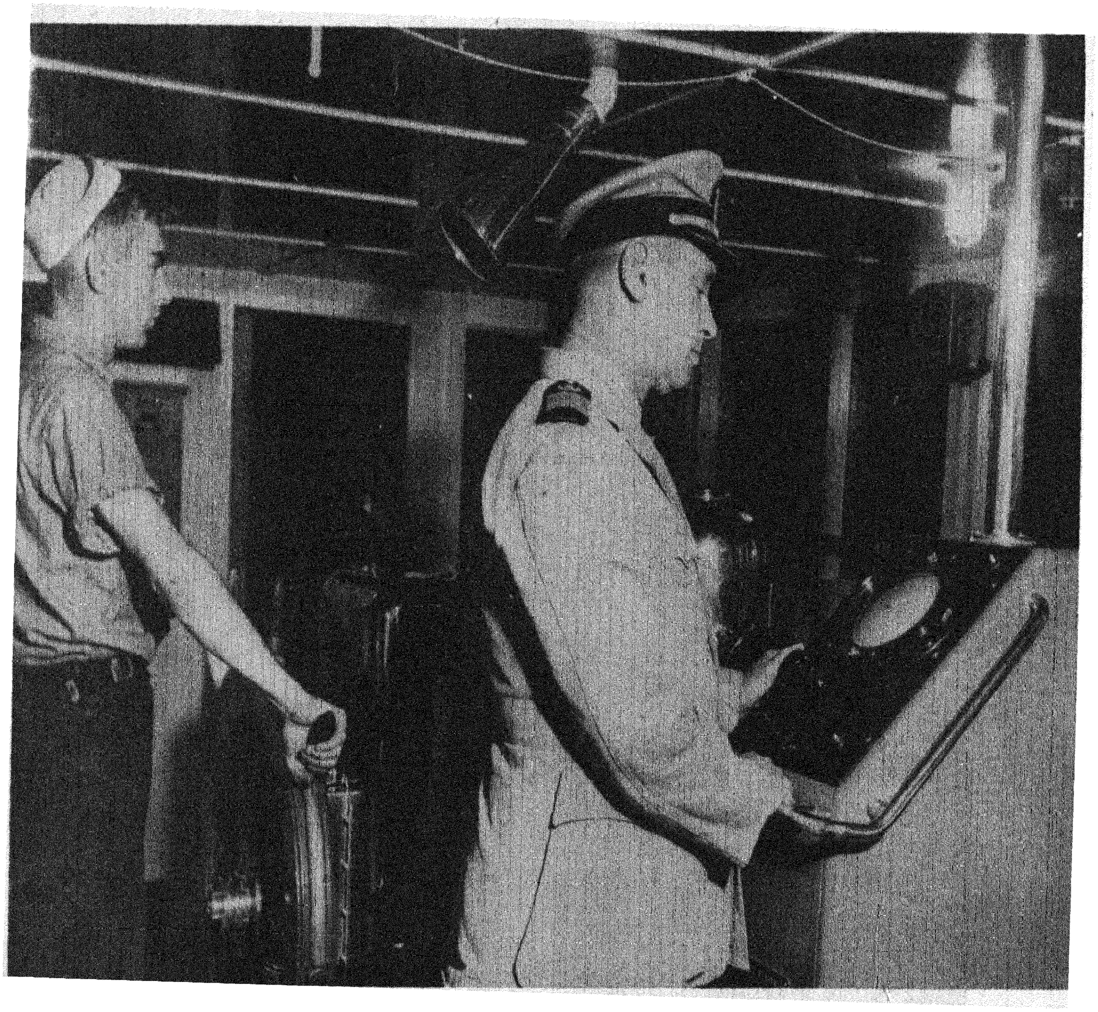


Fig. -14. View of wheelhouse showing another type of radar indicator installation.

CONSIDERATIONS INVOLVED IN THE SELECTION AND INSTALLATION OF A MERCHANT MARINE RADAR

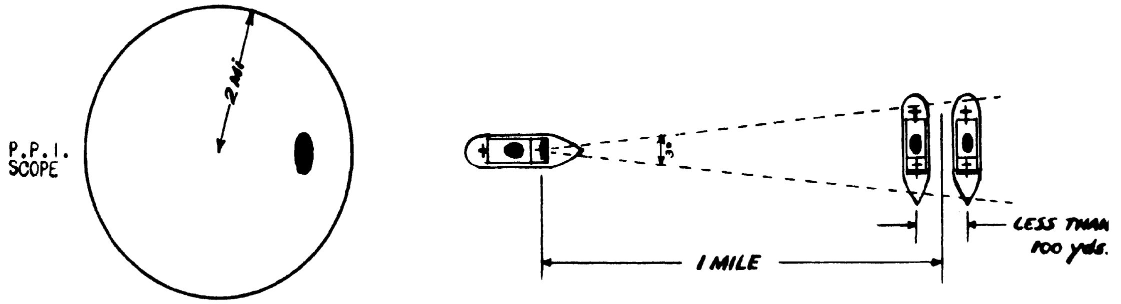
Two factors are most important in selecting a merchant marine radar: the use to be made of the equipment, and the installation problem encountered on the ship to be equipped. Commercial radars have been purposely designed to be somewhat versatile and some compromises have been necessary. Due, however, to the many factors involved in the design of any radar equipment, each type offers certain advantages. It was the purpose of the advisory specifications, in fact, to outline the characteristics considered desirable for various applications. The following paragraphs, therefore, are intended to point out the considerations involved in the selection and installation of a commercial type radar, and to indicate the reasons for some of the requirements contained in the advisory specifications.

RESOLUTION: Due to the type of presentation on a PPI, resolution is divided into two components, resolution in range and resolution in bearing. Resolution in range is the ability to distinguish between two targets on the same bearing and closely spaced in range. (See fig. 3-15). Resolution in bearing is the ability to distinguish between two targets at the same range but slightly different bearings. (See fig. 3-16). While the result of good resolution in range and bearing is a clear sharply defined PPI picture, giving an accurate contour of land and definite pips for small targets, a radar of poor resolution would have a blurred and fuzzy appearance with targets blending together on the scope.

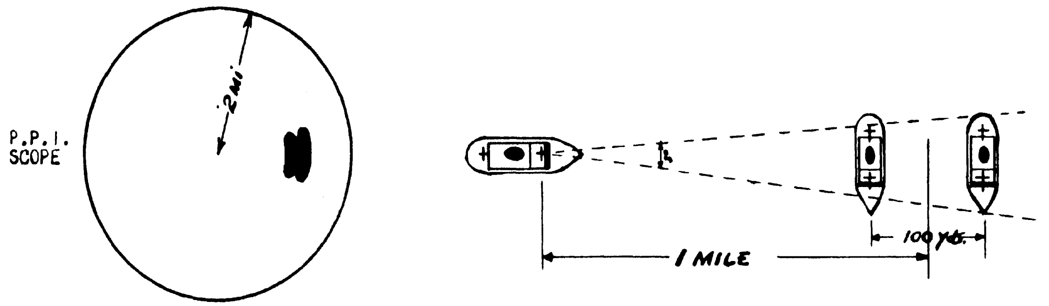
The resolution in range is a function of pulse length, pulse shape, and receiver fidelity. While the returning echoes are successively amplified by each of the intermediate frequency and video circuits of the receiver, should these circuits modify the returning echoes, poor range resolution will result. The optimum band pass of the receiver should consequently be from 1.2 to 1.5 times the reciprocal of the pulse duration in microseconds. As the pulse duration T in microseconds is equivalent to 164T in yards any targets separated by less than this value will appear as a single target.

The resolution in bearing is directly dependent on antenna beam width. For any set frequency, beam width is a function of the antenna dimensions, decreasing as the antenna dimensions increase. Fortunately, as we narrow beam width to improve resolution,

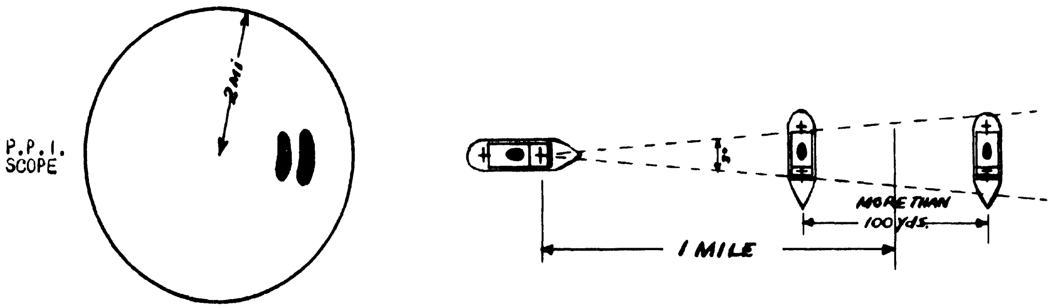
RANGE RESOLUTION



A. PIPS ON SCOPE ARE BLENDED TOGETHER WHEN DISTANCE IN RANGE BETWEEN SHIPS IS LESS THAN DESIGNED RESOLUTION FOR RANGE.



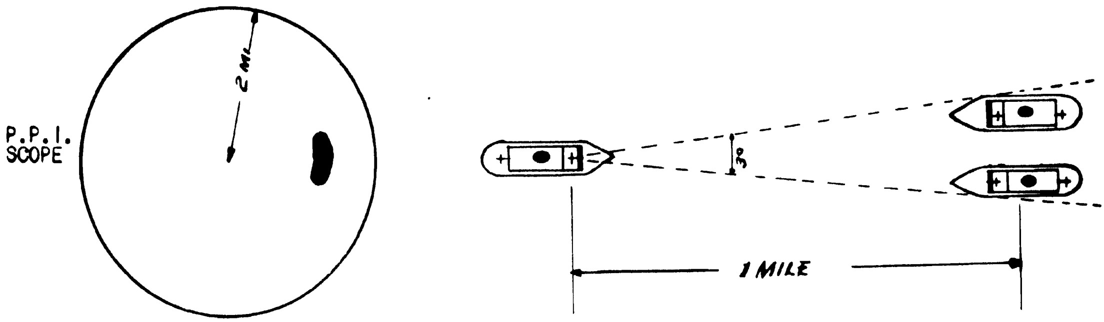
B. PIPS ON SCOPE ARE TANGENT WHEN DISTANCE IN RANGE BETWEEN SHIPS IS THE DESIGNED RESOLUTION FOR RANGE.



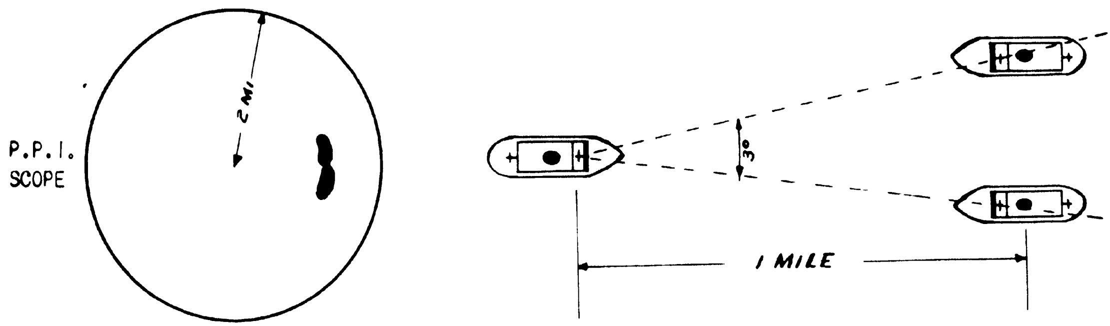
C. PIPS ON SCOPE ARE DISTINCT FOR EACH SHIP WHEN DISTANCE APART IN RANGE IS GREATER THAN DESIGNED RESOLUTION FOR RANGE.

Fig. 3-15.

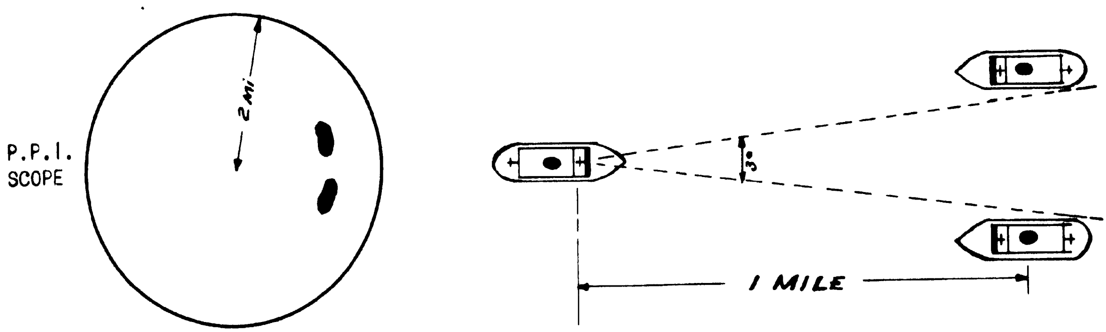
BEARING RESOLUTION



TWO TARGETS WITHIN THE BEARING RESOLUTION APPEAR AS A SINGLE PIP.



TWO TARGETS SEPARATED BY THE BEARING RESOLUTION ANGLE APPEAR AS TWO TANGENT PIPS.



TWO TARGETS SEPARATED BY MORE THAN THE BEARING RESOLUTION ANGLE APPEAR AS TWO SEPARATE PIPS.

Fig. 3-16.

we increase the over-all gain of the antenna system. However, there is a practical limit of about 1° or 2° where further narrowing of the beam causes targets to be missed due to the small number of pulses that will strike it as the antenna scans the target.

Fanning or spreading of the beam in the vertical plane is desired to eliminate any necessity for stabilization of the antenna, that is to retain energy on the surface as the ship rolls. This in turn considerably reduces the vertical dimension of the antenna. The wide beam in the vertical plane will result in some loss of azimuth resolution ahead as the ship rolls, and abeam as the ship pitches, which again brings out the futility of decreasing the horizontal beam width beyond about 1° or 2°. If the PPI is not stabilized in azimuth (true bearing presentation) there will be an appreciable decrease in bearing resolution and a smearing of the picture as the ship yaws. Another limitation, though relatively unimportant with antenna beam widths above 2°, is the consideration of how closely the PPI scan can be made to follow the antenna.

It is extremely difficult to design a reflector that will direct the radiated energy in a pencil beam. There are generally some side lobes of radiation. These lobes in the horizontal plane should be sufficiently small to be relatively unimportant as compared to the main lob. In most cases, if these side lobes are from 25 to 35 decibels down, no further difficulty will be encountered. No harm results from side lobes in the vertical plane other than wasted energy directed skyward.

In addition to the above, both range and bearing resolution will be limited to the size of the spot of light on the scope caused by the electron beam. Because of this spot, which is not pin point and is the same on all range scales, the range and range scale at which the desired resolution is expected should be stated. For example, in figures 3-15 and 3-16, the resolution is illustrated at 1 mile on the 2-mile scale.

Because of the many factors entering into resolution it is generally expressed as the result to be expected providing the equipment has been designed properly for these factors.

COVERAGE: Because of the fundamental nature of the electromagnetic waves employed in radar the coverage of a surface radar will be improved by increasing either the antenna height, or the frequency or both. At the present time, however, there is a practical limit to which the frequency may be increased. The

attentuation of electromagnetic waves by the atmosphere is a function of frequency and increases at an amazing rate at frequencies corresponding to wavelengths below 3 centimeters. Likewise at the shorter wavelengths such conditions as rain, snow, and fog appreciably reduce coverage. Over-all consideration indicates the most desirable wavelength insofar as coverage is concerned would be somewhere near 3 centimeters with good results obtainable with wavelengths as long as 10 centimeters.

In general, a radar is limited in coverage to about 15 percent beyond the visible horizon, and has a minimum practical range limit of approximately 100 yards. (See fig. 3-17). The maximum range is increased by increasing the height of the antenna and in a like manner a higher object will be observed at a greater range. It is not unusual for a good radar to pick up objects as far away as 100 miles providing they are above the visible horizon. Atmospheric conditions play an important part in range coverage at distances greater than 10 or 15 miles. However, we are primarily interested in vessels located in the area between the minimum range of the equipment and the horizon. The subject of the vertical beamwidth has a bearing on range coverage. The beam must be sufficiently wide in the vertical to illuminate with electromagnetic energy all targets from the minimum range to the maximum in order that all ships will be indicated.

Power output has a considerable bearing on range coverage. It is well known that the reflected energy from the target to the antenna is an inverse fourth power function increasing to a much higher power inverse function at a distance somewhat short of the horizon. Hence small increases in power do not mean much in increased efficiencies. At the same time the realized power is considerably affected by the losses in the transmission line and antenna, the antenna gain, the receiver gain, and other factors. A large amount of power is essential to insure the indication of all above water objects in the vicinity of the radar. The real target illumination will also be a function of the pulse rate and speed of antenna rotation as the radar is pulsed at the same time that the antenna rotates. Electromagnetic waves cannot pierce conducting surfaces of any practical thicknesses. Therefore, masts, stacks, and other obstructions will give shading effects, and objects located in the shade of these obstructions will not be indicated. The desirable speed of antenna rotation is tied in with the cruising speed of the vessel and the retentivity of the PPI tube. One might reason that by

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increasing the frequency and repetition rate, that more desirable coverage might be obtained with a small antenna. This, however, is not true. We cannot pulse faster than the time required for the return of echoes.

With too low a pulse repetition rate targets will be passed over as the surrounding area is scanned while too slow a scanning rate will not keep a continuous picture on the PPI scope because of fading of the illumination after the beam has swept by the target. Therefore, with a slow antenna rotation a low pulse repetition rate should be used and conversely with a fast antenna rotation a high pulse repetition rate would be needed. A compromise is consequently necessary. A speed of antenna rotation from 6 to 15 times per minute and a pulse repetition rate greater than 800 pulses per second produces the best results.

INDICATOR DISPLAYS: On the indicator is presented all the information collected by the radar. Although there are many ways of presenting this information the PPI is considered the most advantageous and desirable from a mariner's point of view. While the distance from the center of the scope to the outer edge represents the range from the radar to the radar horizon, this range may be set to suit the individual needs of the user depending upon the areas in which he will operate and possible use to the scale of the charts. Generally a number of different range scales are available to be selected at will. The choice of the lowest range scale, although dependent on magnification desired for operating in confined areas, has a lower limit dependent largely on the resolution.

The size of the PPI scope will to some extent govern the range scales that should be used. The size of the scope, however, is essentially a matter of individual preference. As the radar provides an excellent means of precisely measuring range and bearing it is believed that range and bearing knobs should be provided with precise means of determining these factors, particularly on the better type radars. Even less expensive radars should retain the means for precise bearing measurement as this factor is predominant in determing whether or not two ships are on a collision course. The methods of determining range generally used are by means of a movable range ring geared to a dial or counter and by using fixed range markers (circles) to which the range of an object may be referred. Means should be provided to eliminate the range circles when not in use.

In measuring bearing, there are two methods available. The first is by considering the top of the scope as being in line with the bow of the ship and measuring the bearing relative to the bow of the ship. This method has distinct disadvantages: as the ship turns in one direction, the pips on the scope move in the opposite direction causing a trail to be left on the scope due to its persistence. In addition the PPI must be closely observed during the turn or later confusion will result in the new placement of objects about the scope. In the second method of bearing indication which has won favor with the Navy, the PPI is stabilized in azimuth so that the top of the PPI is always north. A marker is then flashed when the antenna is pointed toward the bow to indicate true heading. This method enables both true and relative bearings to be determined readily, preserves the resolution of the equipment and does not have the undesirable feature of the relative bearing presentation. The picture on the scope is then similar to a chart with the addition of the movable objects. For this latter method, however, the ship must be gyrocompass-equipped.

INSTALLATION: To meet the varying requirements for installation, commercial radars have been broken into 2, 3, or 4 packages. One package, for example, may be the indicator alone, or the indicator and receiver. The transmitter-modulator unit may be a separate package to be installed in any convenient location. Or the indicator, receiver, modulator, and transmitter may be combined in a single package. The antenna is generally a separate unit, but in some cases may have the transmitter and modulator units mounted with or near it in a water-tight cabinet. The photographs of commercial radar installations illustrate the diversity of packaging that has been done. On direct current ships a converter or motor generator is required which can be located where it may receive proper attention.

Locating the antenna is a special problem. While in the case of naval installations antennas were mounted on the masts, this may present difficulties on a merchant vessel due to the use of the masts to support rigging for cargo handling. It is desirable, however, from the standpoint of coverage that the antenna be located as high as practicable. It is also desirable that the antenna be located so that 360° azimuth coverage is provided. A satisfactory solution in some cases has been to place the antenna on a short tower or platform mounted above the pilot house. In any event it is poor economy to pay a relatively large amount for a radar and then limit its capabilities by failing to install the antenna in a good position.

ADVANTAGES AND LIMITATIONS OF RADAR

Radar is definitely not a "cure-all" to replace other devices and methods of navigation, but is rather a supplement to such devices and methods. The chief advantage of radar is that it succeeds in those conditions where other methods are impossible; i. e., in fog, heavy rain, and other conditions of poor visibility. These conditions, however, do have a decided effect upon any radar set and it is well to have an understanding of these effects in order to utilize the radar to the fullest extent when it is most needed. An understanding of the effect of wind on radar is also important. These and other conditions, of course, tend to impose limitations on any radar, and are therefore discussed in some detail in the following paragraphs. The extent to which these things affect the usefulness is of course dependent upon the design of the particular equipment, the experience of the user, but all radars are affected to some extent.

In the open water the effects of wind are most pronounced. The wind by itself gives no trouble but the attendant sea results in an obscuration of the radar known as "sea return". The waves present myriads of targets for the radar signals to detect, with the most pronounced effect being in the direction of the sea. (See fig. 3-18). Sea return may be visible up to 10 miles depending upon the sea conditions and the design of the radar set. Merchant marine radar sets are now equipped with devices for minimizing the effect of sea return and permitting more or less normal operation of the set. While such devices are quite effective they do not wholly remove the sea clutter in bad weather. With careful conning of the ship it is usually possible to pick up large targets such as ships, before they get close enough to get into the sea return. It is also possible in most cases to properly manipulate the receiver gain control and sea return suppressor to detect ships inside the range of the sea return because a ship normally gives a larger concentrated echo than do waves. The radar set in this condition is operating at reduced sensitivity and will of course miss small targets which may still be a source of potential danger to the ship. As an example of failure to pick up a small target, a ship on a southerly course standing into a harbor with a southerly wind of 30 to 40 miles per hour, observed that the small buoys at the breakwater entrance could not be detected, regardless of how the radar controls were manipulated. The breakwaters themselves and the shoreline, however, were easily visible, thus permitting safe

Fig. 5-1[illegible]. [illegible] picture showing [illegible]
anti-clutter or sea return suppression
devices are in use (special 3 cm. radar).

navigation. The effects of wind are somewhat reduced on the Great Lakes, when compared to ocean travel, in that the ship master usually can and does lay his course to take advantage of any lee afforded by the surrounding land.

Rain, snow, sleet, and clouds are generally observed to have a somewhat similar effect on the picture observed on the scope. If the ship is in the midst of a general rain, radar operation will probably be normal or there will be a slight haze on the screen. In the case of heavy concentrations of precipitation, usually local in nature, the actual area and location of the storm will be seen on the scope. During this time the radar detects normally in the other areas of the scope and will probably see targets on the same azimuth as the storm but either closer to or beyond it. (See fig. 3-19). Present experience on the Great Lakes indicates such storms to be of relatively short duration. Radar detection of clouds, heavy precipitation, (cold fronts, etc.) is being exploited by meteorologists in weather predictions.

The operation of radar in fog is usually good and can be relied upon although there may be a reduction in the range at which targets are first detected. It is reiterated, however, that all other means of safety precautions must be continually used by the navigator.

It is apparent, therefore, that the navigator must as always be particularly vigilant during periods of inclement weather, and must use more care in operating the radar and in studying and using the data obtained from it.

Other factors which more or less impose limitations on radar are tabulated and briefly discussed below:

(1). Objects cannot be readily identified unless additional electronic devices (radar aids) are used in conjunction with the radar itself. Identification, however, can quite often be accomplished by implication such as movement, relation to other objects, shape (coastline), and sometimes initial range of detection.

(2). Radar chart presentation on the scope requires interpretation due to line of sight characteristics which give shadow effects. In other words, larger intervening objects may blank out objects behind them.

Fig. 3-19. PPI picture showing portion of sea area (left hand portion of picture) obscured by a heavy rain squall which is local in nature (special 3 cm. radar).

(3). Radar can be used reliably for only slightly over line of sight distance.

(4). Certain types of objects because of their characteristics or motion may go undetected. For example, the Coast Guard's study of radar detection of floating ice has revealed that while icebergs can ordinarily be observed, pieces of ice large enough to damage a ship may go undetected. Ice and some other things, therefore, due to physical characteristics and reflecting properties, are relatively poor targets. A low lying point of land is another example of a relatively poor target. The motion of small objects, such as small buoys and boats, caused by bobbing up and down in a seaway also tends to reduce the echo returned to the radar. These considerations become particularly important when such things as sea return, rain, etc., are present to initially reduce the radar visibility.

While radar has limitations, its advantages more than compensate for these limitations. The distinct operational advantages are summarized below:

(1). It is the best anticollision device yet perfected.

(2). It makes for greater safety while piloting or making landfalls during periods of low visibility.

(3). It indicates continuous instantaneous ranges and bearings of objects.

(4). It presents a chartlike picture of the surroundings, the presentation being in the nature of a polar chart with PPI presentation.

(5). By observation of the scope, movement of objects may be noticed.

DEVELOPMENTS AND EXPERIMENTS IN RADAR NAVIGATIONAL AIDS

A considerable amount of investigation and development work has been undertaken to determine what types of radar aids are necessary and practical to install. Three general types of aids, as follows, have been considered:

(1). Radar reflectors;

(2). Continuously pulsing beacons;

(3). Responder type beacons.

Radar reflectors are metallic devices designed so as to provide in concentrated physical size a radar target equivalent in reflecting efficiency to a much larger object of random conformation. Various types of reflectors have been designed and tested using both 3 centimeter and 10 centimeter radars. Results have been most satisfactory using a basic type trihedral reflector unit, the number and arrangement of which can be varied to meet different application requirements. (See fig. 3-20). The dimensions of these basic units were chosen and proven by test to be optimum for the frequency range of all present types of commercial radar. All tests made so far have indicated that reflectors are most useful to mark objects or points where no reliable radar targets already exist, such as on low lying sandy beaches, small buoys, etc. They are also useful to a limited extent to increase the effective reflecting area of poor targets in order to increase the range at which they will provide a good echo. While reflectors can be useful for specific purposes they have limitations, and do not serve to particularly amplify an already good radar echo. Several particular applications of radar reflectors have been investigated with varying results. For example, it is desirable to mark the channel under a bridge, lock openings, etc., where large reflecting objects are already present. In cases such as this, reflectors attached to or near the bridge or lock are obscured by the echo from the bridge or lock itself. In the case of using reflectors to mark low lying sandspits and other obstructions that might otherwise go undetected on the radar scope, results have been most gratifying. Results also vary to some extent depending upon the frequency of the radar being used for a particular application of a reflector. Radar reflectors, therefore, have only special application and each installation will, in general, be a separate problem. No permanent installations of reflectors have as yet been made, as the subject still remains a continuing project for experimentation and development.

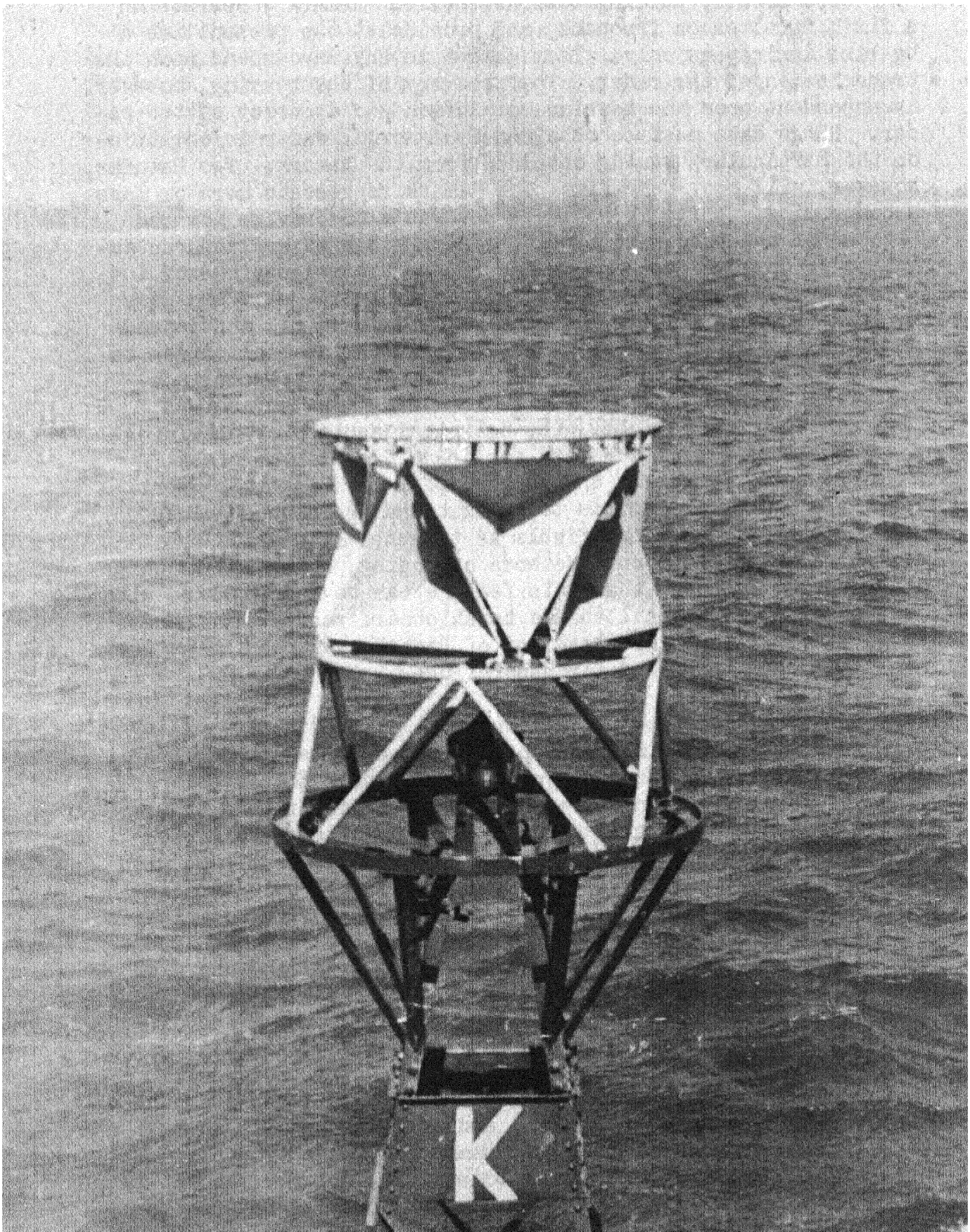


Fig. 3-20. Circular cluster of radar reflectors installed on a buoy.

Continuously pulsing beacons, called "Ramark", operate on a fixed radarbeacon frequency and provide at the presenttime a bearing indication only. They do not in any way depend upon the transmission of the radar. The accuracy of the bearing, however, is dependent upon the bearing resolution and accuracy of the radar. Range data must be obtained from normal radar information on the particular bearing obtained from the Ramark. Two Ramarks, however, will provide a fix. The Ramark represents more or less a compromise. While it would be desirable to provide powered beacons of the responder type, the Ramark has several characteristics which overcome some of the inherent complications of the responder type. The Ramark is relatively inexpensive and easy to maintain, has a low power requirement, is simple and dependable, and is relatively adaptable to inexpensive application to shipboard radars of various types. For several reasons, however, this type device has limitations and, like reflectors, presents special problems. The technical aspects of providing a coded signal from the Ramark for identification purposes have presented problems, and the use of Ramark in its present form, therefore, is limited to navigational reference points which are otherwise identifiable as to general location by normal radar information. Methods of coding, however, are under study and it is hoped that this feature can be incorporated with only a slight additional change to shipboard radar being necessary. Various test installations of Ramark have been made, but none have been installed for general use.

The responder type beacon sends out a coded reply when triggered by an incoming radar pulse, and provides range, bearing, and identification. Such a system is of course highly desirable from a purely operational standpoint. A beacon of this type, called "Racon", was designed during the war and is still used today as a navigational aid for military aircraft equipped with certain types of radar. In order to provide all this information the equipment is of course relatively expensive, complex, and difficult to maintain. While the advantages of this type beacon are many, the problem of adapting it to marine use with commercial radars is a difficult one because of the many engineering complexities of reconciling such factors as the different pulse repetition rates, pulse lengths, and frequencies of the various types of commercial radars. Utilization of this type beacon would therefore require a considerable amount of change to the shipboard radar, and the expense of such must of course be balanced against the demand for this type service. Investigations are continuing in this field, however, and it is hoped that a simplified responder type beacon will be practicable to install.

The entire problem of radar aids has many ramifications and requires a great deal more investigation. Little can be said regarding the probable future status of these devices as such is dependent upon a great many factors, and the eventual installation of any or all of them will probably be a compromise between operational desirability and economy.

Fig. 3-21.

(A) A picture of the chart showing the entrance to the Narrows in New York Harbor.

(B) A picture of the plan position indicator of a radar set aboard a vessel approaching the Narrows in New York Harbor. The vessel is approximately west of Rockaway Point and almost due south of the Narrows.

(C) A composite picture of the chart showing the entrance to the Narrows in New York Harbor and a picture of the plan position indicator of a radar set aboard a vessel approaching the Narrows in New York Harbor. The vessel is approximately west of Rockaway Point and almost due south of the Narrows. It should be noted in (C) that there is some distortion present due primarily from imposing a polar chart on a Mercator projection. In addition, low shore lines do not present a specific target. Any object above the surface of the water that reflects energy back to the radar antenna is presented on the scope. Hence, many targets are reported by the radar that may not be readily apparent to the eye of an observer. The salient features of the surrounding area is presented distinctly enough, however, to allow a navigator to determine his position from the outstanding topographical features.

The value of radar aids installed in restricted waters should be apparent. The radar aids would identify the points of land or objects on which they were installed.

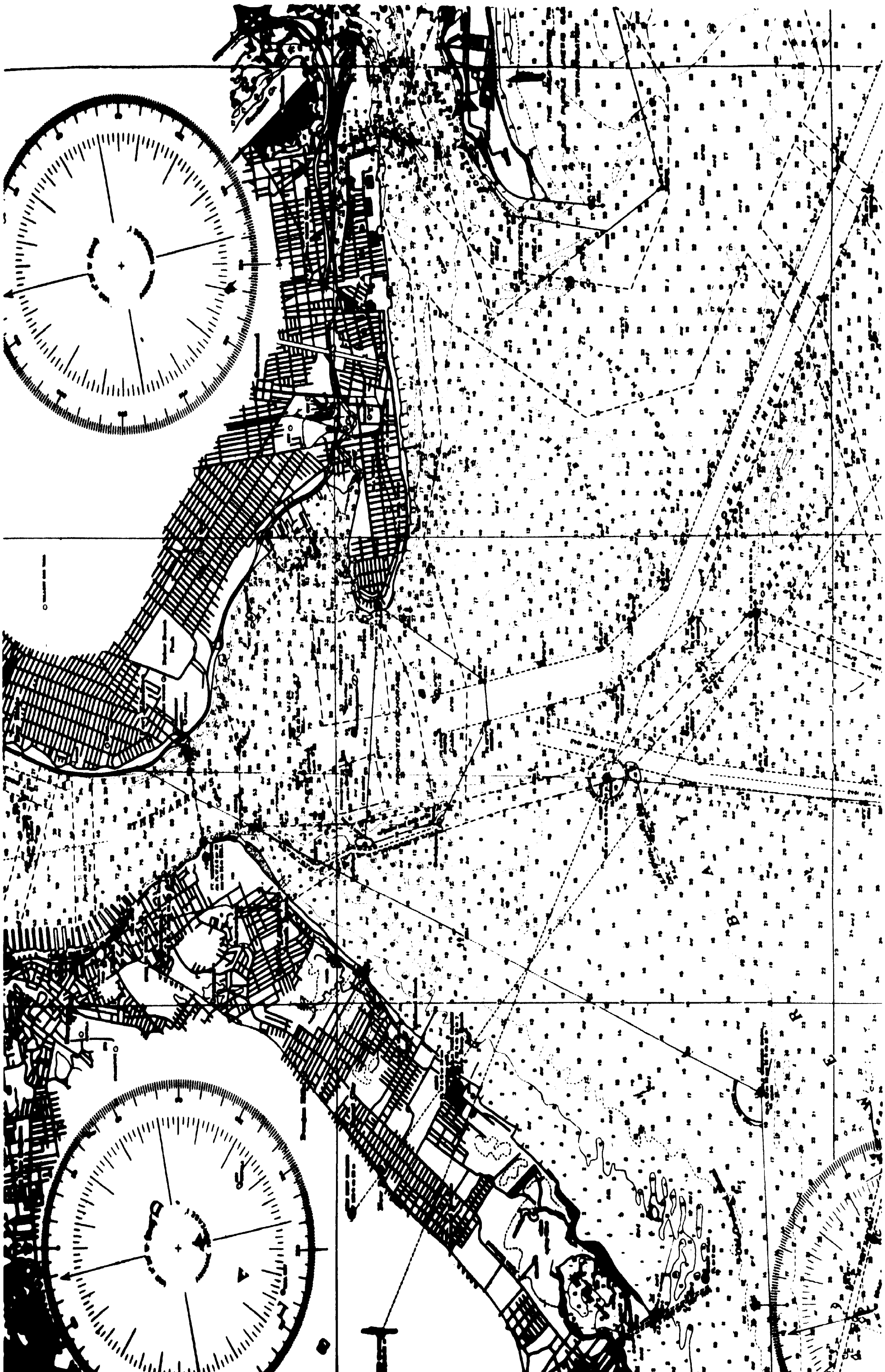


Fig. 3-21 (A).

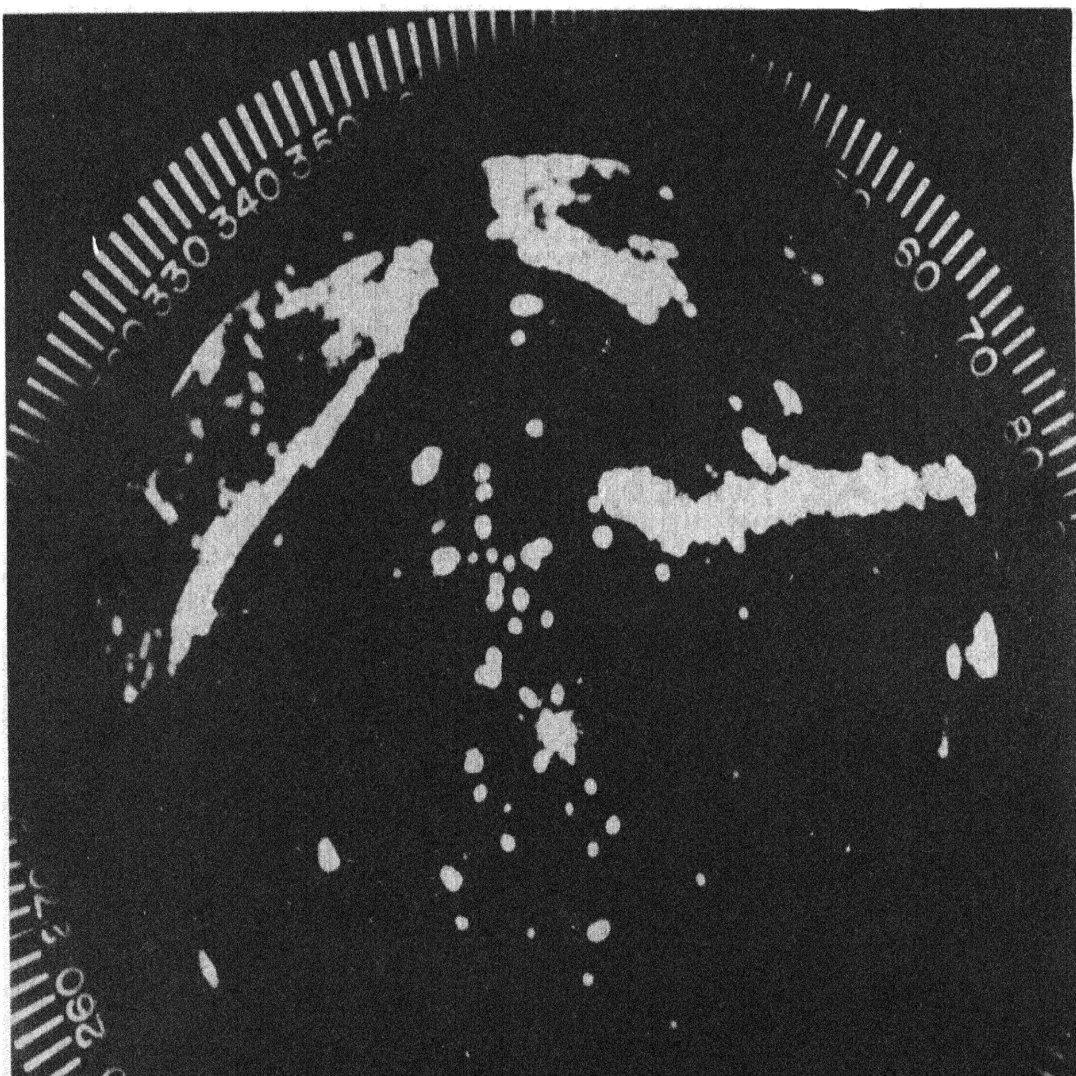


Fig. 3-21 (B).

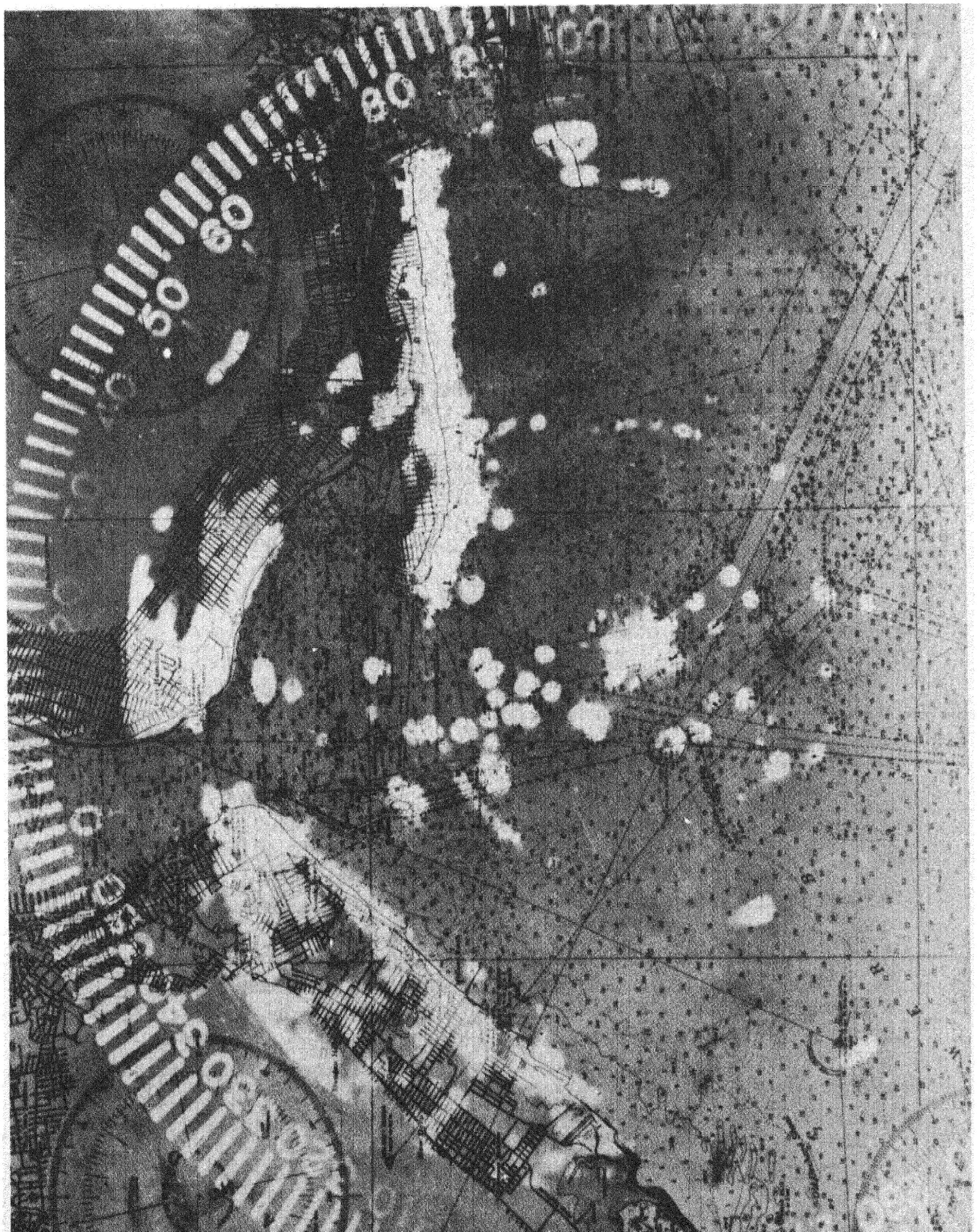


Fig. 3-21 (C).

APPENDIX

THE ADVISORY MINIMUM SPECIFICATION BRIEFS

It is reiterated that it is the intent of the specification briefs to serve only as a guide for voluntary use by parties interested in commercial navigational radar. It is to be noted that the specification briefs are revised only up to August 1, 1946. Some revisions have been agreed upon since August 1, 1946, but a revised version of the briefs has not as yet been issued. It is also to be noted that Brief No. 1 is in two parts, one for a 3 centimeter radar and the other for a 10 centimeter radar. The latter part was added to the original specifications because much investigation and discussion with interested parties indicated that a 10 centimeter radar to fulfill the general requirements of Specification Brief No. 1 has a definite place in the commercial radar field.

Advisory Minimum Specification Brief No. 1 (3 centimeter)

I. Designation

Surface search and navigational radar.

II. General Description

This is to be a 3 centimeter surface search radar, primarily designed for ocean-going vessels to provide early warning of approaching vessels and navigational dangers on the open seas as well as high resolution for navigation in restricted waters.

III. Operational Requirements

Designed for operation by bridge personnel with little or no technical training. The operation of this equipment must not cause interference with other aids to navigation or to communication equipment on board and should be adequately shielded to prevent interference to the radar from other electronic apparatus normally carried. The indicator unit shall not cause appreciable error in a magnetic compass when located more than 6 feet from the indicator nor shall other components cause error when located a distance of more than 15 feet. Mechanical noise from the indicator shall not be audible for more than 20 feet in still air.

IV. Performance

Range—
Maximum - 30 miles.
Minimum - 100 yards.

Resolution--
A properly designed radar with pulse length and antenna beam width as elsewhere prescribed in this specification brief should give a range resolution of 100 yards and a bearing resolution of 2^{o} on the shortest sweep scale.

V. Indication and Output Data

Indicator--
At least 7 inch PPI Scope (plan position indicator). Sweep linearity shall not deviate more than $\pm$ 2 percent except that the first and last 10 percent of the sweep may deviate by $\pm$ 5 percent.

Range scales--
Capable of being set as desired by purchaser within the following limits: 2-5 miles; 4-15 miles; 15-30 miles; a positive range scale indicator is to be provided.

Range indicator--
A variable range marker with a range of 500 yards to 30 miles, accuracy $\pm$ 2 percent or $\pm$ 50 yards whichever is greater or a direct reading range indicator.

Bearing indication--
Stabilized PPI presentation (true bearing display), bearing cursor; ship's head indicator; variable azimuth illumination.

VI. Performance Indicator

Positive means should be provided to indicate whether or not the over-all operation of the radar is such that it may be relied upon to provide effective anticollision and navigational information.

VII. Antenna

Truncated parabola or equivalent.

Beam width--
Horizontal - 2^{o} maximum at half power points.
Vertical - Such as to prevent the transmitted beam from leaving a target on the horizon during a roll of $\pm 7\frac{1}{2}^{o}$. To accomplish this the antenna may be stabilized or have a vertical beam width of 15^{o} at half power points.

Mounting--
Navy Standard Flange ($16\frac{1}{2}$ inch bolting circle with eight

13/16 inch holes equally spaced, two opposite holes on center line).

Rotation—

Continuous, 360° in azimuth, speed of rotation 6 to 15 revolutions per minute with the specified transmitter and modulator characteristics. In the event a higher speed of rotation is desired, peak power and other characteristics of the modulator and transmitter should be raised sufficiently to compensate for a decreased return due to fewer "hits" per revolution of the antenna. Control on main on-off switch. Antenna reversing switch may be provided to sector scan.

Side lobes—

At least 25 decibels down.

VIII. Transmitter

Frequency recommended - 3 centimeter band, 9320 to 9430.

Radio frequency source - Magnetron.

Modulator - Hydrogenthyratron, hard tube, or equivalent.

Main transmission line - the over-all attenuation from the radio frequency source to the radiator must not be more than 3 decibels one way.

Peak power - 15 kilowatts minimum.

Pulse repetition rate - Minimum 800 cycles per second.

Pulse length - 0.5 microsecond maximum.

Trigger - Positive 10 to 50 volts (across high impedance).

IX. Receiver

IF, RF and video band pass - Optimum for pulse length chosen.

Over-all gain - 120 decibels minimum.

Video output - 2.5 volts ± 0.5 volts (across 75 ohms).

Over-all noise above KTΔf - 15 decibels maximum.

Features--

Automatic frequency control; fast time constant; sensi-

tivity time control or equivalent circuits to minimize interference from sea return and adverse meteorological conditions.

X. Power Requirements

The equipment shall be designed to take power from a source of 115 volts, 60 cycles per second, single phase with a regulation of $\pm$ 10 volts and $\pm$ 2 cycles per second. In the case of direct-current equipped ships and ships with poor regulation, auxiliary power equipment will be necessary.

XI. Operator Controls

On-off switch (all power).

Bearing cursor knob.

Range marker knob.

Continuous gain control.

Limited intensity control; focus to be essentially independent of intensity.

Range selector (positive range scale indicator).

STC, FTC selector switch for varying degrees of any or all (sea return and interference suppressor).

Azimuth scale light control.

Antenna-reversing switch (optional).

Safety devices shall be incorporated to make it impossible for the operator to damage the equipment by manipulation of the controls.

XII. Construction Features

Replaceable units with chassis type assembly.

Fuze alarms.

Mounting, tropicalizing and weather proofing shall be suitable for intended installation.

XIII. Installation Features

The antenna assembly must be so mounted as to provide 360° clearance to the horizon. The indicator is to be mounted in the pilot house. To facilitate this arrangement on all types of vessels it is suggested that the radio frequency components, the antenna assembly and the indicator be manufactured in separate units.

XIV. Special Provisions for Future Modifications

As contemplated, 3 centimeter radar beacon objectives will meet 3 centimeter commercial radar design objectives on the common ground that the radar will be able to transmit within the frequency limits and with peak radiated powers as specified herein, and further that it will be capable, as constructed or with minor modifications, of receiving beacon signals on 9310 megacycles.

XV. Optional Features

Remote PPI's with controls independent of the indicator controls, for installation in the chartroom, commanding officer's quarters, etc., have obvious uses on certain classes of vessels. Such remote PPI's may have a means for comparison with navigational charts and/or giving an expanded presentation of a selected area of the PPI.

An "hours run" meter to facilitate the replacement within the required period of components which deteriorate with age.

XVI. Remarks

Standard Navy flange for antenna mounting, standard video output and standard trigger output are specified to facilitate ease of conversion for military use.

The phrase "or equivalent" is applicable to all the above items. As radar is still in a progressive stage, these specifications are intended merely as a mutual, voluntary starting point. It is reiterated that nothing in these specifications should be construed as limiting development and improvement of radar circuits or equipments extant.

Advisory Minimum Specifications Brief No. 1 (10 centimeter)

I. Designation

Surface search and navigational radar.

II. General Description

This is to be a 10 centimeter surface search radar, primarily designed for ocean-going vessels to provide early warning of approaching vessels and navigational dangers on the open seas as well as good resolution for navigation in restricted waters.

III. Operational Requirements

Designed for operation by bridge personnel with little or no technical training. The operation of this equipment must not cause interference with other aids to navigation or to communication equipment on board and should be adequately shielded to prevent interference to the radar from other electronic apparatus normally carried. The indicator unit shall not cause appreciable error in a magnetic compass when located more than 6 feet from the indicator nor shall other components cause error when located at a distance of more than 15 feet. Mechanical noise from the indicator shall not be audible for more than 20 feet in still air.

IV. Performance

Range—
Maximum - 30 miles.
Minimum - 100 yards.

Resolution—
A properly designed radar with pulse length and antenna beam width as elsewhere prescribed in this specification brief should give a range resolution of 100 yards and a bearing resolution of 4° on the shortest sweep scale.

V. Indication and Output Data

Indicator—
At least 7 inch PPI scope (plan position indicator). Sweep linearity shall not deviate more than $\pm$ 2 percent except that at the first and last 10 percent of the sweep may deviate by $\pm$ 5 percent.

Range scales—
Capable of being set as desired by purchaser within the following limits: 2-5 miles; 4-15 miles; 15-30 miles; a positive range scale indicator is to be provided.

Range indicator—
A variable range marker with a range of 500 yards to 30 miles, accuracy ± 2 percent or ± 50 yards whichever is greater or a direct reading range indicator.

Bearing indication--
Stabilized PPI presentation (true bearing display), bearing cursor; ship's head indicator; variable azimuth illumination.

VI. Performance Indicator

Positive means should be provided to indicate whether or not the over-all operation of the radar is such that it may be relied upon to provide effective anticollision and navigational information.

VII. Antenna

Truncated parabola or equivalent.

Beam width—
Horizontal - 4° at half power points.
Vertical - Such as to prevent the transmitted beam from leaving a target on the horizon during a roll of ± 7½%. To accomplish this the antenna may be stabilized or have a vertical beam width of 15° at half power points.

Mounting—
Navy standard flange (16½ inch bolting circle with eight 13/16 inch holes equally spaced, two opposite holes on center line).

Rotation—
Continuous, 360° in azimuth, speed of rotation 6 to 15 revolutions per minute. Control on main on-off switch. Antenna reversing switch may be provided to sector scan.

Side lobes--
At least 25 decibels down.

VIII. Transmitter

Frequency recommended - 10 centimeter band, 3000 to 3246 megacycles (See par. XIV).

Radio frequency source - Magnetron.

Modulator - Hydrogenthyratron, hard tube, or equivalent.

Main transmission line - the over-all attenuation from the radio frequency source to the radiator must not be more than 1.5 decibels one way.

Peak power - 15 kilowatt minimum.

Pulse repetition rate - Minimum 800 cycles per second.

Pulse length - 0.5 microsecond maximum.

Trigger - positive 10 to 50 volts (across high impedance).

IX. Receiver

IF, RF and video band pass - Optimum for pulse length chosen.

Over-all gain - 120 decibels minimum.

Video output - 2.5 volts ± 0.5 volts (across 75 ohms).

Over-all noise above $KT\Delta f$ - 15 decibels maximum.

Features—
Automatic frequency control; fast time constant; sensitivity time control or equivalent circuits to give the operator optional control over interference from sea return and adverse meteorological conditions.

X. Power Requirements

The equipment shall be designed to take power from a source of 115 volts, 60 cycles per second, single phase with a regulation of ± 10 volts ± 2 cycles per second. In the case of direct-current equipped ships and ships with poor regulation, auxiliary power equipment will be necessary.

XI. Operator Controls

On-off switch (all power).

Bearing cursor knob.

Range marker knob.

Continuous gain control.

Limited intensity control; focus to be essentially independent of intensity.

Range selector (positive range scale indicator).

STC, FTC selector switch for varying degrees of any or all (sea return and interference suppressor).

Azimuth scale light control.

Antenna-reversing switch (optional).

Safety devices shall be incorporated to make it impossible for the operator to damage the equipment by manipulation of the controls.

XII. Construction Features

Replaceable units with chassis type assembly.

Fuze alarms.

Mounting, tropicalizing and weather proofing shall be suitable for intended installation.

XIII. Installation Features

The antenna assembly must be so mounted as to provide 360° clearance to the horizon. The indicator is to be mounted in the pilot house. It is suggested that the radio frequency components, the antenna assembly and the indicator be manufactured in separate units.

XIV. Special Provisions for Future Modifications

As contemplated, 10 centimeter radar beacon objectives will meet 10 centimeter commercial radar design objectives on the common ground that the radar will be able to transmit within the

frequency limits and with peak radiated powers as specified herein, and further that it will be capable, as constructed or with minor modifications, of receiving beacon signals on 3256 megacycles. Beacon operation will be improved if the operating frequency of the radar is in that portion of the radar band as close as practicable to the beacon frequency.

XV. Optional Features

Remote PPI's, with controls independent of the indicator controls, for installation in the chartroom, commanding officer's quarters, etc., have obvious uses on certain classes of vessels. Such remote PPI's may have a means for comparison with navigational charts and/or giving an expanded presentation of a selected area of the PPI.

An "hours run" meter to facilitate the replacement within the required period of components which deteriorate with age.

XVI. Remarks

Standard Navy flange for antenna mounting, standard video output and standard trigger output are specified to facilitate ease of conversion for military use.

The phrase "or equivalent" is applicable to all the above items. As radar is still in a progressive stage, these specifications are intended merely as a mutual, voluntary starting point. It is reiterated that nothing in these specifications should be construed to limit development and improvement of radar circuits or equipments extant.

<u>Advisory Minimum Specification Brief No. 2</u>

I. Designation

Surface search and navigational radar.

II. General Description

This is to be a 3 or 10 centimeter surface search radar primarily designed for ocean-going vessels to provide early warning of approaching vessels and navigational dangers on the open seas as well as fair resolution for navigation in restricted waters.

III. Operational Requirements

Designed for operation by bridge personnel with little or no technical training in scope interpretation. The operation of this equipment must not cause interference to or be affected by other navigational and electronic equipment normally carried aboard ship.

IV. Performance

Range--
Maximum - 30 miles.
Minimum - 400 yards.

Resolution--
A properly designed radar with pulse length and antenna beam widths as elsewhere prescribed herein should give a range resolution of 200 yards and bearing resolution of 6° on the shortest sweep scale.

V. Indication and Data Output

Indicator--
At least 7 inches PPI (plan position indicator) scope. Sweep linearity shall not deviate more than $\pm$ 3 percent except that the first and last 10 percent of the sweep may deviate by $\pm$ 7 percent.

Range scales--
Variable 2-5 miles; 4-15 miles; 15-30 miles; positive range scale indication is to be provided.

Range indication--
Fixed electronic range markers; accuracy of $\pm$ 2 percent or $\pm$ 100 yards, whichever is greater; not more than five range circles appearing on the scope.

Bearing indication--
True or relative bearing indication with bearing cursor; over-all absolute bearing accuracy from antenna to display $\pm$ 3°.

Positive means should be provided to indicate whether or not the over-all operation of the radar is such that it may be relied on to provide effective anticollision and navigational information

VI. Antenna

Truncated parabola or equivalent.

Beam Width—
Horizontal - 5° maximum to half power points.
Vertical - 15° minimum (7.5 either side of horizontal) to the one-half power points.

Mounting—
Navy standard flange ($16\frac{1}{2}$ inch bolting circle with eight 13/16 inch holes equally spaced, two opposite holes on center line.

Polarization—
Horizontal or vertical.

Rotation—
Continuous, 360° in azimuth, speed of rotation 6 to 15 revolutions per minute; control on main on-off switch. Antenna reversing switch, may be provided to sector scan.

Side lobes—
20 decibels down.

VII. Transmitter

Frequency recommended - 3000 to 3246 or 9320 to 9500 megacycles.

Radio frequency source - Magnetron.

Modulator - Hydrogenthyratron, hard tube, or equivalent.

Main transmission line - the over-all attentuation from the radio frequency source to the radiator must not be more than $1\frac{1}{2}$ decibels one way on the 10 centimeter band nor more than 3 decibels one way on the 3 centimeter band.

Peak power-- 15 kilowatts on 3 centimeter band and 7 kilowatts on 10 centimeter with the above transmission line attenuation limits.

Pulse repetition rate - minimum of 800 pulses per second.

Pulse length - 1 microsecond maximum

Trigger - Positive 10 to 50 volts (across high impedance).

VIII. Receiver

IF, RF, and video band pass - Optimum for pulse length chosen.

Over-all gain - 120 decibels.

Video output - 2.5 volts ± 0.5 volts (across 75 ohms).

Over-all noise above $KT\Delta f$ - 15 decibels maximum.

Features—
Automatic frequency control or equivalent. Fast time constant and sensitivity time control or equivalent.

IX. Power Supply

The equipment should be designed to take power from a source of 115 volts, 60 cycles per second, single phase with a regulation of ± 10 volts ± 2 cycles per second. In the case of direct-current equipped ships and ships with poor regulation, auxiliary power equipment will be necessary.

X. Operator Controls

On-off switch (all power).

Bearing cursor knob.

Range marker intensity knob.

Continuous gain control.

Limited intensity control; focus to be essentially independent of intensity.

Range selector (positive range scale indicator).

STC and FTC selector switch for varying degrees. (Sea return suppressor).

Azimuth scale light control.

Antenna-reversing switch (optional).

XI. Construction Features

Replaceable units with chassis type assembly.

Fuze alarms.

Mounting, tropicalization, and weather proofing shall be suitable for intended installation.

XII. Installation Features

The antenna assembly must be so mounted as to provide 360° clearance to the horizon. The indicator is to be mounted in the pilot house. To facilitate this arrangement on all types of vessels it is suggested that the radio frequency components, the antenna assembly, and the indicator be manufactured in separate units.

XIII. Special Provisions for Future Modifications

The radar should be capable as constructed or with minor modification of receiving radar beacon signals on 3256 megacycles for a 10 centimeter radar or on 9310 megacycles for a 3 centimeter radar. Beacon operation will be improved if the operating frequency of the radar is in that portion of the radar band as close as practicable to the beacon frequency.

XIV. Remarks

Standard Navy flange for antenna mounting, standard video output and standard trigger output are specified to facilitate ease of conversion for military use.

The phrase "or equivalent" is applicable to all the above items. As radar is still in a progressive stage, these specifications are intended merely as a mutual voluntary starting point. In using these specifications the constant improvement and development of radar should be contemplated and kept in mind.

<u>Advisory Minimum Specification Brief No. 3</u>

I. Designation

Anticollision radar.

II. General Description

This is to be a surface search radar primarily designed as an anticollision device with a limited value for navigational purposes.

III. Operational Requirements

Designed for operation by pilot house personnel with little or no technical training but with specialized operational training in the interpretation of equipment data. The operation of this equipment must not cause interference to or be affected by other navigational and electronic equipment normally carried aboard ship.

IV. Performance

Range maximum--

Equipment must be capable of absolute indication of the presence of a C2 type cargo vessel or equivalent at a distance of 7 miles.

Minimum - 500 yards.

Accuracy - $\pm$ 5 percent or $\pm$ 500 yards whichever is greater.

Bearing--

Equipment must be capable of giving an over-all bearing accuracy of $\pm$ 5° using as a target a C2 cargo vessel or equivalent at a distance of 7 miles.

V. Indication and Output Data

Indicator - 5 inch scope or larger, PPI (plan position indicator) prefferred.

Range - Electrical or mechanical to meet requirements of paragraph IV.

Bearing - Mechanical dial or equivalent.

Positive means should be provided to indicate whether or not the over-all operation of the radar is such that it may be relied on to provide effective anticollision and navigational information.

VI. Frequency

Any channel authorized for use of commercial radar.

VII. Antenna

A motor-driven train is to be provided, with arrangements for shifting to manual train for bearing determination. Minimum

speed of rotation, 5 revolutions per minute. In case an A scope is used, it is to be understood that it must be continuously manned by trained personnel if the anticollision features are to be realized. Should a PPI scope be used, the provision for hand train may be eliminated and the speed of the rotation may be increased to 15 revolutions per minute. The. beam width in the vertical plans must be at least 20°.

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN. · · · APRIL 28-MAY 9, 1947

THE MARINE USE OF GEE

1. At the 1st IMRAMN it was agreed that, whenever possible, and expedient, radio aids to navigation should be used in common for civil aviation and shipping (I.M.R.A.M.N. Vol. I, para. 5.60.3). Consequently the U.K. examined in detail the possibility of using the Gee system as a combined air/sea navigational aid.

2. There is no doubt that with suitably sited stations and a counter method of presentation of readings the Gee system would be a valuable navigational aid to ships. But owing to the limited coverage at sea level of a system in the 20-80 Mc/s part of the spectrum eleven chains of stations, situated near the coasts, would be required to give adequate marine coverage around the British Isles. The provision of these chains would take at least 5 years and would be unduly costly in relation to other systems. These eleven chains would give marine coverage only up to about 100 miles from the coast. Moreover, these chains alone would not satisfy the needs of aircraft, including air traffic control.

3. There are other systems of radio navigational aids which give greater marine coverage and accuracy at less cost than Gee and it must therefore be concluded that overall common air and marine use of Gee is not desirable economically or operationally.

4. However the U.K. plan for the use of Gee by aircraft will provide useful marine coverage, in limited areas, and user trials of the system have been carried out in the "QUEEN ELIZABETH" and on three or four small vessels. The "QUEEN ELIZABETH" is at present retaining her Gee equipment for operational use, especially as a land-fall aid in the S.W. approaches to the British Isles.

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN. · · · APRIL 28-MAY 9, 1947

RADIO BEACONS AND M.F. D/F.

Introduction.

1. At the first IMRAMN it was agreed that shipborne M.F. D/F with the associated shore radio beacons, was a valuable aid to navigation and should be maintained, improved and extended. The United Kingdom has been following this policy, directing attention more to the radio beacons than to the shipborne equipment.

2. Two main problems have been examined in some detail - first, the most suitable form of signal to be transmitted by radio beacons; and second, the possibility of integrating marine and air radio beacons with consequent economy in equipment and frequencies. Other questions which have been examined are the construction of beacon aerials so as to give the best radiation pattern, and the provision of an adequate calibration service for ship' direction finders. From consideration of the coverage of radio beacons, views have been formulated on the probable future of the radio beacon system.

3. A new specification has been drawn up for shipborne direction-finding equipment which seeks to improve appreciably the standard of this equipment, and consideration has also been given to the use of automatic or visual direction-finding equipment.

4. Less attention has been paid to shore-based M.F. D/F but an investigation has recently been started into the possibility of integrating the several M.F. D/F services at present in existence.

RADIO BEACONS AND M.F. D/F.

Form of Signal.

5. Only the existing type of radio signal, namely a modulated continuous wave, has been considered, since this has been regarded as the most satisfactory. It has been suggested, however, that there would be an advantage in using unmodulated continuous wave transmissions to narrow the frequency band required, and it is known that other types of signal, in which for example only the side-bands are keyed, have been suggested. No investigation has been made of the relative merits of these different signals.

6. Within the category of modulated continuous wave transmissions consideration has been given to the best form of signal, i.e. the best sequence of Morse characters and dashes. There are a surprising number of different radio beacon signals in use though all have certain features in common - for example, all start with a number of repetitions of the call sign of the particular beacon and all contain one or more long dashes intended for taking the bearing, but within these broad limits the variations are considerable. Because of the large number of different types of signal in use, it was decided as a first step to consult ships habitually using beacons on the U.K. coastline, and obtain views of their relevant merits. A questionnaire was drawn up asking amongst other things for views on the rate, duration and nature of the transmissions from existing beacons.

Over 300 replies were received, and although this is a low percentage of the questionnaires distributed, valuable information was obtained and an analysis of them has brought out the following points. There was a slight preference for the slower rate of transmission, 10-12 words per minute, rather than the fast rate of 16-20 words per minute. Under the existing Paris International Regional Agreement of 1933 beacons are arranged in groups of 3 and operate on a 6 minute time-sharing cycle, each beacon transmitting successively for slightly less than 2 minutes followed by 4 minutes silence whilst the other two are transmitting. With the existing signals there was a general reluctance for the duration of transmission of each beacon to be reduced much below its present 1 minute 50 seconds. As for the composition of the signal, the most important result was the general demand for a long uninterrupted dash for taking the bearings, and there was a strong preference for a high-pitched note.

7. In framing general conclusions from the analysis of replies, about the type of signal which should be provided, it was realised that some of the replies came from Masters or Navigating Officers and others from Radio Officers. The Radio Officer is accustomed to receiving wireless signals and skilled in reading Morse, whereas Masters and Navigating Officers in general would be relatively unskilled in such matters, and would therefore probably prefer a much simpler and slower signal than the average Radio Officer.

As a matter of principle it is considered that a form of signal should be provided suitable for Masters and Navigating Officers, because they are responsible for the handling and safety of the ship and should be able to take the bearings themselves; moreover some ships do not carry Radio Officers.

8. The United Kingdom has been pressing on continuously with the installation of those radio beacons provided for by the Paris International Regional Agreement of 1933. As part of this programme two new beacons are about to be installed at Smith's Knoll and Shambles, and this provides an opportunity for further investigation of the best form of signal. After consideration of the replies of the questionnaire it is proposed that, for one beacon, the signal consist of

> 4 repetitions of 1, 2 or 3 dots; followed by 4 repetitions of the code signal; followed by a 2-second warning dash; followed by a short silence; followed by a 13-second bearing dash; followed by a short silence; followed by a final repetition of the code signal.

This sequence would occupy about 40 seconds and would be repeated to give a total time of about 80 seconds. For the other beacon a similar signal is proposed, but with the repetitions of groups of dots and of the code signal increased from 4 to 9 (or 10), so that the signal occupies the whole 80 seconds, and the final code signal replaced by a group of dots. One of the principal features of these signals is the introduction of groups of 1, 2 or 3 dots, according to the position of the beacon within its group, as an additional simple aid to identification for the Navigating Officer unskilled in reading Morse. A single long uninterrupted dash is provided for taking the bearing, which is preceded by a short dash as a warning. The total time of the signal has been reduced to about 80 seconds in order (at some future date) to accommodate more than 3 beacons in a 6-minute period.

9. These signals do not represent a final judgment on the best form. They will be introduced on the two new beacons and the

views of Masters and Navigating Officers will be sought. It should then be possible to state with some certainty what is in fact the most suitable type of signal. Complete international standardisation may not be possible or even desirable, but it is believed that the results of this investigation will be generally welcomed and will lead to a very desirable reduction in the number of different signals in use.

Coverage

10. It is of interest to consider at this stage to what extent a radio beacon system is capable of meeting the mariners' stated requirements as a coastal or landfall aid. An analysis based on the known accuracy of ships' loop-type direction finders shows that coverage up to the higher standard of accuracy agreed by the first I.M.R.A.M.N. (Vol. 1 of report, p.56) for a land-fall and coastal aid is limited to a very small area, but a lower order of accuracy may be obtained at a range of 20-30 miles. Experience also shows that beacons of errors due to reception of an obliquely polarised sky-wave the range for accurate D/F bearings should be restricted to not more than 25 miles at night and 100 miles by day. It is apparent therefore that no radio beacon system of reasonable dimensions can provide comprehensive coastal coverage with the accuracy desired by the mariner. It is nevertheless true that in many areas where particular difficulties may be experienced it is possible to arrange a local system of beacons to provide most valuable assistance, and the policy of extending and improving the beacon system as recommended at first I.M.R.A.M.N. is supported by the U.K.

11. It has been suggested that a single Consol Station might replace a number of M.F. beacons and give an equal service over the same area but making a smaller demand upon frequencies. This suggestion has not been investigated in detail but has obvious promise. A single Consol beacon would provide an accuracy at least as good as that obtained from M.F. beacons up to 30 miles range, within an area extending 150 miles along the normal to the base line, 120 miles along the radii at $\angle 30^\circ$ to the normal and 70 miles at the edge of coverage at $\angle 60^\circ$ to the normal, but excluding ranges less than 25 miles. There are some difficult points to be examined, such as the siting of stations to provide good cuts in the required areas, but it is considered that this suggestion shows sufficient promise to warrant careful investigation before any attempt is made to extend greatly the coverage provided by the radio beacon service.

Construction of Beacons

12. The ranges which have been quoted for accurate bearings from radio beacons are based on the assumption of vertically polarised

radiation, with a cosine polar diagram in the vertical plane. Since the sky-waves are of steep-angle it is possible for an aerial with an appreciable horizontal component to reduce the accurate range by radiating more energy at steep angles. It is hoped that beacons installed in the future will have aerials free from unsymmetrical horizontal portions, and as far as possible to modify existing radio beacon aerials which may be particularly bad in this respect. It is of interest to note that where a beacon is appreciably above sea level it is possible for an aerial with a horizontal component to introduce a few degrees of error into bearings taken at close range. This may not be serious in normal navigation, but is important in calibration of ships' direction finders.

Calibration Service.

13. The existing method of calibrating ships' direction finders in the U.K. is by requesting a radio beacon to operate on the fog schedule. This is inadequate in many respects - for example, the schedule necessarily involves periods of silence between transmissions because of the system of 3 beacon time-sharing groups. A ship trying to calibrate its direction finder would have to lay off during these intervals. This increases the time required for calibration and may be difficult or dangerous in bad weather or busy areas. The transmissions from the beacon are unnecessarily powerful for calibration purposes since calibration must be carried out within visual range of the beacon. Also these transmissions are on a single frequency, and it is therefore not possible to take account of differences in calibration at different frequencies.

14. To overcome these objections, it is intended to instal special low-power calibration transmitters, in the first instance at eight radio beacons around the British Isles. The special calibration transmitters will have an output power of only about 1/4 watt but will operate continuously and simultaneously on three frequencies - namely in the radio beacon band from 290 to 320 kc/s, in the band 365 to 380 kc/s, and in or near the distress band of 485 to 515 kc/s.

Integration of Marine and Air Radio Beacons.

15. Another major problem which has been tackled in connection with radio beacons is the possibility of integration of marine and air radio beacons, with consequent economies in equipment and frequencies. It was found that radio beacons are used by aircraft primarily for holding and homing, and the majority of air beacons are therefore sited inland at airports or on principal air routes, and operate on low power giving comparatively short ranges. The Mariner on the other hand uses radio beacons primarily for fixing his position at distances up to about 50 miles off shore. Also

the marine system of operating beacons in groups on a time-sharing basis would not be suitable for the air uses because of the high speed of aircraft. It was evident that as long as radio beacons continue to be used only at comparatively short ranges, no large scale integration of marine and air beacons will be possible. The majority of the air beacons will be too far inland to give cover at sea, and integration will only be possible locally in the few places where an air beacon is required near the Coast. The use of radio beacons at longer ranges, which would give the only hope of large-scale air and marine integration, is prevented by the fundamental obstacle of the low accuracy of the system when used in conjunction with loop-type direction finders.

Shipborne Direction-Finding Equipment

16. A new specification has recently been drawn up covering the performance of ships' direction finding equipment, and will form the basis of type approval tests. By this means equipment in keeping with modern standards will be introduced. Among other features the new sets will be capable of receiving either modulated or unmodulated continuous wave transmissions.

17. Consideration has been given to the use of automatic D/F. At one end of the scale are complicated equipments with cathode-ray tube presentation, with which a skilled operator can obtain bearings even under the most adverse conditions and can give a reasonable estimate of the accuracy of the bearing obtained. Present opinion is that the equipment is too complicated and expensive, especially in view of the comparatively low accuracy inherent in the M.F. beacon system, and shipowners are deterred by the need for a more skilled operator, greater maintenance problems and overall expense. At the other end of the scale is fully automatic equipment such as the radio compass which has several attractions. It is extremely simple and in reasonable conditions would enable the most unskilled operator to obtain a bearing at least as accurate as he could obtain by the aural method. The primary disadvantage of this type of equipment is that if the signals suffer from interference the equipment may not be sufficiently selective to indicate the true bearing and will give a false intermediate bearing. In these circumstances the present aural method gives better results. Therefore until the frequencies of radio beacons can be so rearranged that there is no possibility of simultaneous reception of two signals, the introduction of fully automatic D/F equipment cannot be seriously contemplated.

M.F. D/F

The first I.M.R.A.M.N. was unanimous on the desirability of

maintaining shore-based D/F for search and rescue, if not as a navigational aid. An adequate M.F. D/F service already exists in the U.K. and the only extension contemplated is to include D/F on 1650 kc/s, which is used by small ships as a distress frequency. Separate services are however provided by the air and marine authorities, and the possibility of integrating these services (with consequent economies) is being investigated.

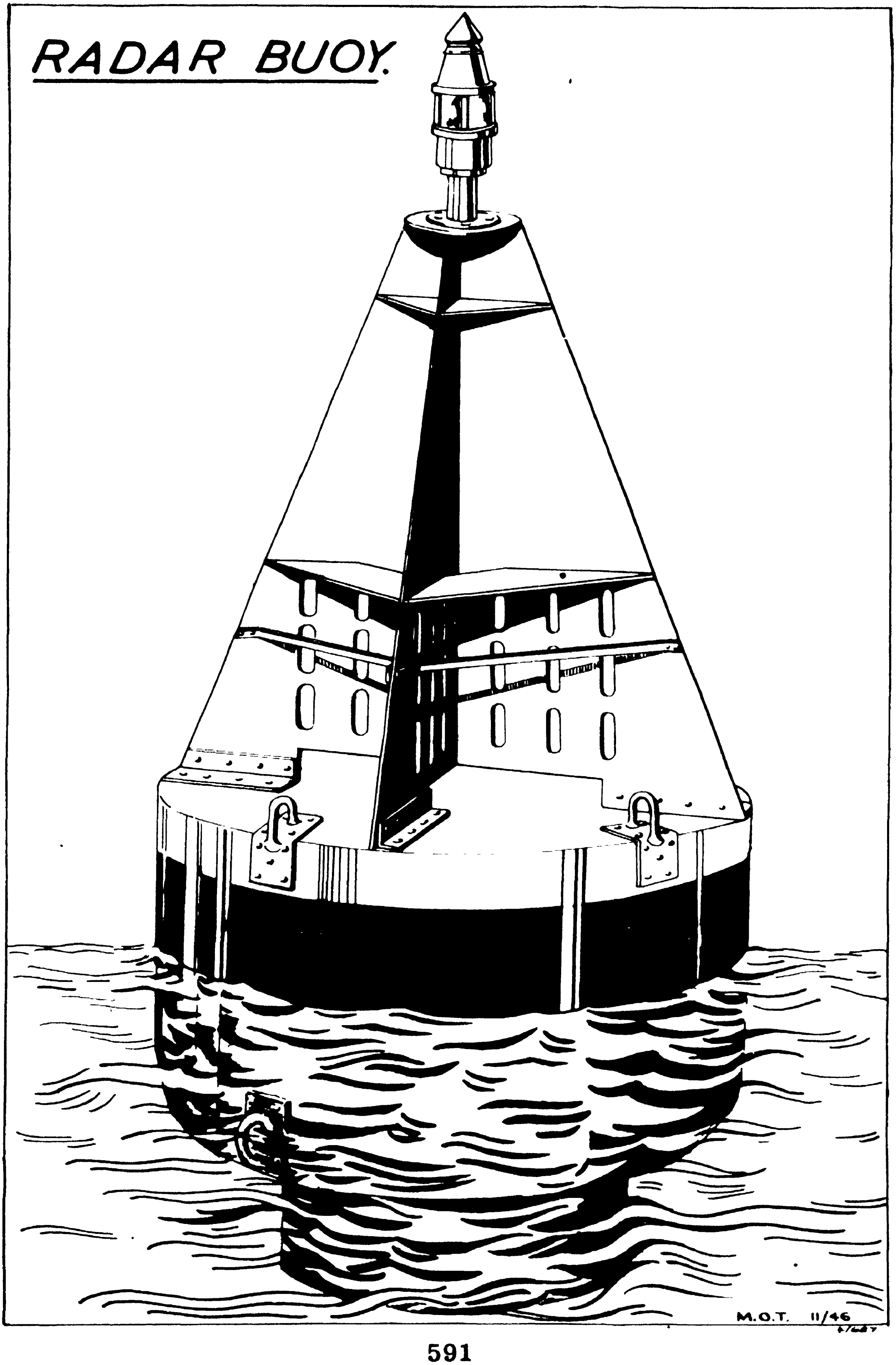
INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN. · · · APRIL 28-MAY 9, 1947

RADAR PASSIVE REFLECTORS

1. Since navigational radar designed to meet the U.K. Specification will have good range and bearing discrimination, the use of passive responders has been considered to be of considerable importance as a radar aid in pilotage waters, especially in view of their simplicity and reliability.

2. Trials have been proceeding at Liverpool and in the Thames Estuary to determine the most convenient and reliable method of providing these radar aids to shipping, especially by increasing the detection range of channel buoys. Typical of developments in this latter direction is a buoy recently tested at Liverpool. A special conical buoy was constructed, consisting basically of two intersecting vertical plates triangular in shape so as to be identical in appearance to a standard conical buoy when viewed from a distance, (see drawing). This construction gives good radar reflecting properties, and has the advantage over fitting a reflector to the top of a standard buoy that the windage area and the likelihood of damage in heavy seas is not in any way increased. Trials were carried out using Type 268 radar, and the reliable radar detection range for the special buoy was about 6000 yards compared with 2000 yards for a conical buoy of conventional construction. The principle of intersecting vertical plates is of course applicable not only to conical shaped buoys.

3. In the Thames Estuary consideration is being given to extending the fitting of corner reflectors to all first-class buoys marking the main channels and possibly utilising suitable patterns of passive reflectors as an aid to identification of outlying dangers and shoals.


RADAR BUOY.
M.O.T. 11/46

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RADAR CHARTS

1. At the first IMRAMN it was agreed that examination should be given to the question of charts specially designed for use with marine radar, particularly with a chart comparison unit. The problem has been considered in the U.K. and whilst it is appreciated that certain amendments are required to make the normal navigational charts suitable for use with radar, it is considered that they should be limited in extent as the chart must retain its main characteristics for what will continue to be its major purpose - visual navigation.

2. After a series of trials around the British Isles and off the Norwegian coast, certain recommendations have been made on the possible adaptation of the normal navigational chart to meet all requirements, including the application of radar navigation. Predominant among these recommendations are proposals for a thickened coastline, emphasis to be placed on outlying dangers, islets, piers, etc., that may appear conspicuous on the P.P.I. buoy symbols to be adapted to radar requirements and chart "tinting" to be used wherever clarity may be gained, to show contrast between land and water, and possibly to show up areas of shallow water.

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RADAR MAINTENANCE

1. Though ship's radio officers have been encouraged to become proficient in the servicing of radar equipment it has been recognized that it might not be possible to have a fully trained maintenance man on each ship to carry out major repairs on board. The U.K. aim has therefore been to provide radar trained staff and full technical facilities at major ports.

2. For type 268 sets, which are fitted in about 250 British ships and in some Canadian ships, the Admiralty has entered into a contract with a commercial firm for providing maintenance facilities at major ports in the U.K. at a flat rate of £7.10.0 per month for each ship. After payment of this flat rate a 268-fitted ship entering any of these ports can have its radar serviced free of charge, and by special arrangement maintenance engineers will travel to other minor ports on payment of the additional expenses involved. As part of the hiring arrangements Admiralty supply the spare parts free of charge to the contractors. The Admiralty has also made similar arrangements with other contractors for maintenance of type 268 in South African and Australian ports.

3. The marine radio operating companies in the U.K. are making arrangements for world-wide maintenance facilities for the commercial marine radar now being developed and produced by British Manufacturers. By the middle of 1947 maintenance facilities for British commercial radar will be available at 15 major ports in the U.K. and at 25 major ports in other parts of the world. This new organisation is also providing maintenance facilities for type 268 sets where not available under the existing arrangements, so that by the middle of 1947 Type 268 maintenance facilities will also be available at about 15 additional ports in different parts of the world.

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RADAR

TRAINING OF RADAR OBSERVERS AND MAINTENANCE ENGINEERS

1. Following the recommendation at the first IMRAMN, the U.K. has examined the question of the qualifications and training of radar operators and maintenance engineers. These two classes have been considered separately.

RADAR OBSERVERS

2. It is intended that the Navigating Officer being trained in radar observation shall be given a general idea in a non-technical way of the principles and mechanism of the radar set, in addition to the main course in radar observation.

3. The ideal training in radar observation is undoubtedly that given afloat, and the ideal arrangement would be to centralise all radar training in a suitably equipped training ship. However, for practical purposes in the near future, it is recognized that instruction will have to be given at shore schools, and in fact it is considered that training in radar observation should become part of the normal training at navigational schools.

4. In deciding the duration of the course, account had to be taken of the desirability of equipping the Observer to make the best possible use of radar, but realising the difficulty of detaching officers to attend long courses with the present general shortage of Merchant Navy Officers. The final decision has been for a course lasting about 11 days. This will be made up of 3 days' lectures and demonstrations of the basic principles of radar equipment, 2 days' practical demonstration of typical equipments, 2 days on the use of radar information as an aid to navigation, 2 days' practical use of existing equipment ashore and 2 days' practical use of the same equipment afloat. This distribution is not intended to be rigid and can be modified to suit different circumstances.

5. Type 268 sets have been installed at four shore schools and courses in radar observation of the type just described have begun or are about to begin. Certificates will be issued to candidates completing the course and attaining a certain standard of proficiency.

6. It is considered that as many officers as can be spared from each ship should attend these courses, and though it may not be desirable to stipulate the precise number of trained officers to be carried it is strongly recommended that the aim should be for each radar-fitted ship to carry at least 3 officers trained in radar observation.

RADAR MAINTENANCE

7. Having in mind that ship-borne radar is in its infancy and therefore needs the highest standard of efficiency in maintenance, it is intended to provide a minimum 8 weeks' course of training for candidates with a sound basic knowledge of radio and electricity, with longer courses for those not so equipped.

8. Steps have been taken to provide suitable courses at four shore schools, at 3 of which radar observation courses are also taking place. Courses have already commenced at one of these, of 8 weeks' duration for candidates holding a First-Class P.M.G. Certificate or equivalent, with an additional 4 weeks for others not so qualified.

9. At the end of the courses trainees will undergo a full practical and theoretical examination, and those who attain the required standard will be issued with Certificates.

10. It may not be necessary or desirable for every ship to carry a qualified radar maintenance engineer, but undoubtedly the fullest maintenance facilities will have to be provided at all major ports. The number and types of ships which should carry their own maintenance engineers is being considered.

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OPERATIONAL EXPERIENCE OF RADAR ON MERCHANT SHIPS

NUMBER OF SHIPS FITTED

1. At the time of the first International Meeting on Radio Aids to Marine Navigation in London, May 1946, some 90 British Merchant Ships were fitted with Naval Type 268 radar sets. The obsolete Type 271 sets which had been fitted to defensively equipped Merchant Ships during the war were being withdrawn. No commercial radar sets conforming with the U.K. Specification had been installed.

2. Since then, fittings of Type 268 sets have increased and the number of British installations now exceeds 250 (this does not include vessels fitted with Type 268 sets by Canada.) It is intended to equip about 15 more vessels in the near future. Nearly all Type 271 sets have been removed.

3. Type 268 sets are fitted to different classes of vessels in the following numbers:-

Fast Passenger Liners	68
Cross Channel Ships	18
Tankers	34
Cargo Liners and Tramps	125
Whaling Factory Vessels	7
Miscellaneous (including Cable Ships)	6
	258

4. The first experimental models produced by commercial firms were fitted in the summer of 1946, and since then about 25 ships have been equipped with commercial sets designed to comply with the U.K. specification, and the number is expected to increase by 40-50 a month in the new few months, and at a higher rate later.

REPORTS ON THE USE OF RADAR

5. During the past year, numerous reports on the use of radar by merchant ships have been received. Most of them concern Type 268 sets, which are at present numerically predominant, but there have

been interesting instances of the valuable service given by commercial radar sets.

6. In spite of the known difficulties of maintenance and the limitations of the Type 268 set, great navigational assistance is generally being obtained from the equipment. The keenness and resource of Radio and Engineering officers in tracing and repairing faults to maintain the radar at maximum efficiency has enabled Masters to obtain beneficial aid in difficult circumstances. It is noticeable from the reports that, when frequent use has given the ships officers both confidence in the equipment and experience in the interpretation of the information provided, the maximum aid is obtained.

Use as a collision warning device.

7. Whenever radar is operated it provides warning of collision and great use has been made of this facility. In conditions of moderate visibility radar enables course to be altered much earlier than might otherwise be the case. The regulations for the Prevention of Collision at sea must however always be borne in mind.

8. The Master of the "TAMELE" (7,200 g.t.) reports:-

> "When sailing homewards along the West African coast, in visibility of 1/2 mile, two vessels were picked up by radar, 11-1/2 miles distant on my starboard bow.
>
> By plotting I could see that one ship was in the same course as the "TAMELE", and the other ship was approaching at 10 knots. I altered course to clear the approaching ship.
>
> In the meantime, the fog cleared, and the radar was found to be correct by visual bearings."

9. Cross channel vessels, since they operate mainly in congested waters, find the anti-collision service provided by radar especially valuable.

10. The "QUEEN ELIZABETH" (83,700 g.t.) is fitted with both a Type 268 set and with a commercial set, and the superiority of equipment constructed to conform with the U.K. specification has been evident. It has been particularly noticeable that the commercial set is less susceptible to sea clutter. It is customary to operate both sets in poor visibility, and with this dual safeguard against

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collision, it is possible to maintain speed. For a ship of the size and speed of the "QUEEN ELIZABETH", it is desirable to know whether an alteration of course is necessary when an approaching vessel is still several miles away. Except in emergency, more than 10 degrees of rudder is never used at speed, and alteration of course is necessary at least 2-1/2 miles ahead in order to give the required clearance.

Use as an aid to coastal navigation.

11. The more experience of radar gained by ship's Masters, the more assistance they receive from it in conditions of poor visibility. Several outstanding coastal passages which would have been impossible but for the use of radar have been reported, and even in good visibility radar has proved a great help in identifying coast lines which are somewhat featureless to the naked eye. The accurate positional data provided by radar will be used to an increasing extent to supplement visual observations of bearing and identity in clear weather.

12. The "MANCHESTER SHIPPER" (7,900 g.t.) fitted with a commercial radar set sailed 245 miles, including the passage of the Belle Isle Strait, in dense fog, and the "PORT LINCOLN" (7,200 g.t.) navigated the English Channel, principally by radar from Bishop Rock to Dungeness thereby saving 4 tides on arrival at Hull. For a ship of this type the financial saving would amount to £585 in standing costs and fuel alone.

13. The Master of the "EMPIRE BYNG" (7,800 g.t.) operating in the Bay of Bengal made a practice of using his radar even on clear days when approaching anchorages or rounding prominent points, in order to familiarize himself with the characteristic radar picture. Thus, when the necessity arose, he was able, with complete confidence, to approach and anchor at Chittagong in heavy rain and on another occasion en route from Chittagong to Rangoon to round the Algueda Reef at night when bad visibility prevailed, without having to await daylight or improved visibility.

14. The "RANGITATA" (16,000 g.t.) outward bound from the Nore, operated her Type 268 set for a continuous period of 18 hours in thick fog. The Pilot reported that the Radar had proved an excellent aid to navigation and that the passage through the Downs would probably have been impossible without it.

15. The "BRITISH MAJOR" (8,000 g.t.) on passage from the Tyne used radar continuously for 60 hours in order to assist navigation in the buoyed channels of the North Sea and English Channel, when poor visibility prevailed the whole time.

16. Cross channel vessels fitted with radar have shown up to great advantage against those not so fitted. The "ISLE OF SARK" (2,200 g.t.) and "BRITTANY" (1,400 g.t.) both left Southampton at the same time. Although dense fog was encountered in the English Channel, the "ISLE OF SARK" arrived at Jersey only 20 minutes late at 9;30 a.m. The "BRITTANY" did not reach Jersey until 2 p.m.

17. The "ALCANTARA" (22,200 g.t.) made a successful radar assisted passage through the Straits of Magellan at night, with fierce wind and rain squalls. Bearings and distances were obtained from the South Coast of the Straits and the Master was able to make accurate allowances for the considerable set and drift experienced. Without radar, the Master would have felt obliged not to attempt the passage at night, but to anchor during the darkness with consequent loss of valuable time.

18. A company operating liners from the United Kingdom to Australia has estimated that a radar fitted ship would save £300 each year solely by the reduction of mileage rendered possible by standing-in closer to certain points than would otherwise be prudent.

19. When approaching the Pit Light Vessel (North Sea) in thick sea fog, the "EMPIRE HALLADALE" (3,600 g.t.) was able to give an American ship her position continuously by W/T messages indicating the vessel's bearing and distance from each channel buoy.

Use as a pilotage aid.

20. With present experience Masters are naturally more reluctant to rely upon radar for the exacting art of Pilotage than for coastal navigation which allows of a slightly greater freedom of movement. However, there have been instances of the successful use of radar to assist navigation in pilotage waters and undoubtedly, as experience is gained, Masters will take increasing advantage of the aid to be obtained from radar in restricted channels.

21. The "CITY OF MADRAS" (8,600 g.t.) approached and entered Cape Town in dense fog, berthing alongside at least 1/2 a day earlier than would otherwise have been possible, with a consequent saving of at least £100 in standing costs and fuel alone.

22. The "KRONPRINS FREDERIK" which is fitted with a commercial radar and is engaged on the cross channel service between Harwich and Esbjerg made a successful entrance into the latter port at a time when all other shipping was at a standstill owing to a fog restricting visibility to 25 yards. A tug which had been sent out to assist the "KRONPRINS FREDERIK" ran aground.

23. The "ISLE OF SARK" (2,200 g.t.) has navigated by radar from Southampton Docks, through the Solent and the Needles Channel when the fog was thick enough to prevent any sight of land even in the mile wide channel between Hurst Point and the Isle of Wight.

24. Fog delay has been minimised on the Dover to Calais Cross Channel service since the "CANTERBURY" (2,900 g.t.), which is on that route, has been fitted with radar. Passengers travelling by the "GOLDEN ARROW" service are seldom held up on account of poor visibility at sea.

Use by whaling factory vessels.

25. Radar has been found to be of great use as a guard against ice, and for observing the formation of ice packs at long range. It has also been found possible in fog to give whale catchers courses to home on the parent ship.

Use in heavy rain, etc.

26. Type 268 radar has now been used in most of the sea areas of the world of importance to shipping, and it is of interest to note that a small fraction only of the reports received refer to the adverse effects of heavy rain in cluttering up the radar picture. Some reports refer to the ability to detect other ships and to recognize landmarks in rain clutter, by use of the gain control. These reports confirm the United Kingdom view that the advantages to be gained by the use of 3 c.m. as the operating wave-length outweight the small disadvantages due to heavy rain etc. There have been no reports of any "black-out" phenomenon.

27. The Master of the "DUNNOTTAR CASTLE" (15,000 g.t.) reports:-

> "Heavy, low-lying clouds cause a blurred picture to be presented on the P.P.I. The experienced and discriminating observer can, however, do much to distinguish between land and cloud echoes, as the latter are ragged, lacking firmness and continuity."

28. The "DEVON" (9,900 g.t.) was able to detect two small vessels in the centre of a rain squall at a range of about 12 miles. "A rain squall presents a fluffy patch on the P.P.I. and the sharp edges and slightly greater brightness of the ship echoes made it possible to pick them out quite easily."

29. Marcus Island, a small low Pacific Atoll, was picked up at 20,000 yards in heavy tropical rain by the radar fitted to the "SILVERWALNUT" (6,800 g.t.).

30. The Master of the "LLANGIBBY CASTLE" reports:-

"On the West African coast, in heavy rain showers, the P.P.I. is cluttered up with rain patches and it is possible for a ship to be blanketed in such a rain cloud and not seen on the P.P.I. However, the danger of missing a ship entirely can to a great extent be obviated by altering the strength of the signals and searching these patches of clutter by means of the gain control".

31. It has been reported that sand haze encountered in the Persian Gulf does not affect radar reception adversely. Whilst making Abadan Bar, with visibility reduced to 2 or 3 miles owing to sand haze, the "BRITISH MARQUIS" (8,100 g.t.) picked up the Bar Light Vessel by radar at 18 miles, and vessels anchored at the Bar at 25 miles.

32. A swept gain unit to minimise sea clutter has recently been developed for the 268 set, and this modification is now being fitted to all installations at the option of shipowners. Reports so far received indicate that performance in choppy weather is considerably enhanced, sea clutter being almost obliterated.

CONCLUSION.

33. Wide operational experience of satisfactory performance during the past year has demonstrated that radar is now eligible to take its place among established aids to marine navigation. The conclusions reached at the 1st International Meeting on Radio Aids to Marine Navigation, regarding the various possible applications for radar are borne out by the reports of service rendered under day-to-day operating conditions.

34. There is by now a large body of Masters with considerable experience in the use of radar, and it is evident that those who have been accustomed to look upon radar as one of their standard aids to navigation are reluctant to sail without it. There is no doubt that radar has been accepted by the Mariner and that it has come to stay.

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RADAR IN THE NORWEGIAN FJORDS.

1. At the end of the 1st IMRAMN Norway suggested that the United Kingdom send a ship fitted with a 3 cm. Radar set, built to the U.K. Specification, to Norwegian Waters to investigate the effect on the set of the peculiar characteristics of Norwegian fjords and coast lines. H.M.S. "FLEETWOOD" carried out Radar trials between Stavanger and Bergen in June, 1946, with a team of Norwegian and British experts.

Reflections from the Coast

2. Before the trials it was thought possible that reflections of side lobes from the steep fjord sides and multiple reflections between ship and fjord wall would produce false echoes that would confuse the picture. Tests in Hardanger Fjord showed that the amplitudes of echoes from large rock faces were surprisingly low and were negligible. At no time were multiple reflections observed.

3. When approaching the coast, land echoes were first seen on the radar set at a range of 12 miles, and these were from scattered points of high ground, and since the chart gave only a poor indication of the topography it was not possible to identify the echoes. When the range was 9 miles the radar picture could be related to the chart. In general the strength of reflections from rock faces in Norway was lower than on the South Coast of Great Britain, due probably to scattering of the pulses by irregularities of the surface and to absorption. The south coast of Britain being more densely populated, reflecting objects such as houses and sea walls tend to increase the strength of echoes, but the geological structure of the two coasts may be partly responsible for the difference in detection ranges.

Radar Assistance to Navigation

4. When entering Stavanger the leading marks could not be

seen by eye because of heavy squalls, but by using the radar set the navigator was able to bring the ship safely through the outer islands to the harbour entrance. Throughout the trials a Chart Comparison Unit provided a practical and safe method of navigation in the fjords except where the scale of the chart was not sufficiently large to use the complete P.P.I. picture with accuracy. In navigation by radar through a narrow entrance using a chart comparison unit the entrance should have a width on the chart and the P.P.I. of at least one inch.

Navigational Marks

5. The tall metal pillar buoys used in Norwegian waters are particularly good radar reflectors and several were detected at 4½ miles in a smooth sea. The conical buoys and the numerous wooden beacons and wooden spar buoys are poor reflectors, and for radar navigation the more important of these should be replaced by tall metal pillar-buoys or fitted with corner reflectors.

Charts

6. As a result of these trials and others around the British Isles recommendations have been made for modifying the normal navigational chart for use with radar (See Brief S.4 (iv) - U.K. Paper No. 8).

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NEW YORK CITY AND NEW LONDON, CONN · · · APRIL 28-MAY 9, 1947

SHORE-BASED RADAR FOR USE BY HARBOUR AUTHORITIES

Summary

1. Within its limited scope the paper describes briefly the more important features of shore-based radar for harbour supervision. Since the first IMRAMN progress has been made in a scheme for the port of Liverpool where plans are moving towards realisation, and this example may be used as a guide for assessing the problems of a more general application.

Introduction

2. Ship-borne radar is already well recognised as an asset - the potentialities of shore-based radar, for harbour supervision in particular, are as yet not so well known. The Port Authority at Liverpool, has placed a contract for the erection of an installation, and the project has reached the stage of advanced design and preliminary construction. The equipment is expected to be in operation in the Spring of 1948, and the proposals have stimulated lively interest amongst other port authorities.

Operational Considerations

3. The installation has been designed to meet fully the present and foreseeable needs at Liverpool. Careful consideration was given to the geographical position of the port; the sea approaches to the Channels; the Channels leading into the port; floating navigational marks, and means of providing improved radar visibility for the small marks; the River on which the port is situated; the means of passing information from the transmitting station to the Port Authority's operational centre; and the provision and maintenance of necessary operational staff for the installation. Having regard to all these factors Liverpool probably provides a major siting problem to achieve the radar cover required.

4. It is clear that requirements at different ports will vary considerably. In general, ports fall into one or other of the

following categories:-

(1) those situated on a river or estuary and having long and possibly circuitous channels;

(2) those situated on a river or estuary and having short approach channels;

(3) those situated on a river or near a seaboard without approach channels.

Those within category (1) will require the full harbour installation, as designed for Liverpool, whilst those within (2) and (3) will probably be satisfied with an installation of less exacting specification. At all ports, the rapid exchange of information between ship and shore is of paramount importance and maximum utility of any installation will depend upon an efficient means of communication being incorporated in the system. Docking and other services will be accelerated, particularly in thick weather by the use of shore radar. Selection of a suitable site is of particular importance and is governed by the geographical and hydrographical conditions at the port concerned. The display arrangements in all cases will also depend upon the geographical features of the particular port and the scale and disposition of the displays will be similarly determined. There is small probability that a stereotyped plan can be produced to suit all harbours. The aim should be a flexibility in design which, while satisfying common features at a number of ports, will be adaptable to the requirements of individual ports after separate investigations have been made.

(A)

Technical Requirements

5. The site selected at Liverpool is on the dock estate at the mount of the River Mersey and complete radar cover over a large area of the Bay, the sea channels, approaches to the seaward limits of the port, and also the river is provided (See Fig.1).

6. A preliminary investigation was made at Liverpool in the Spring of 1946 with a mobile 3 cm. radar equipment. The pictures given were quite good but the performance proved not to be fully adequate. A precision 'B' Scope was added to the display equipment, which improved the discrimination, but it still remained unsatisfactory and gave poor discrimination due mainly to the $1\frac{1}{4}^{\circ}$ beam width.

7. Following these trials a very careful investigation into the precise requirements for an equipment which would provide really effective harbour supervision was carried out. The opportunity was also taken to give some consideration to the requirements of other typical ports and harbours to ascertain whether a single equipment could be produced which would satisfy requirements at a majority of ports. In the result it appeared that some parts of the equipment could be standarised but a large measure of individual planning would be necessary for each particular harbour.

8. At Liverpool the major requirements are:-

(a) the equipment must have a very high discrimination and should be better than 1^{o} in bearing, and about 40 yards in range;

(b) the displays must be large-scale and something in the region of 1 in 30 or 40,000 is considered satisfactory;

(c) in conditions of high shipping density, confusion of echoes from navigational buoys and from ships would be easy and means of identifying the fixed navigational marks must be included in the displays; in addition, it will be required to fix the position of a ship with accuracy and speed;

(d) the equipment will often be used by a single non-technical operator and must be simple to use; it is of the utmost importance that the equipment gives clear, unmistakable pictures.

(e) At first the radar information will be displayed only at the installation site and will be communicated to the Harbour Authority's Office by private telephone line. It is preferable that the Authority by provided with radar displays in the Office, and the equipment should be planned so that remote displays can be added at a later date. The equipment should be thoroughly reliable and capable of operating continuously for perhaps several days when conditions of visibility demand. Maintenance should not require the continuous attendance of a highly skilled technician.

9. The equipment planned is in the development stage and will have the following general characteristics. To achieve a bearing discrimination of better than 1^{o}, a large aerial scanner

unit weighing approximately $1\frac{1}{2}$ tons has been designed and will be mounted on the top of an 80 ft. stoel tower. The aerial mirror is mounted on the top of a cabing containing the driving mechanism and the bearing transmission units. This form of construction lends itself to easier routine attention of motor and gear since it is possible for a man to enter the cabin and work in comparative comfort. Despite the large size of the mirror, it has been designed to extremely close tolerances in order to keep down the side lobes to the smallest possible value and to ensure that these tolerances will be maintained despite the effects of very high winds and large ranges of temperature. Heaters have been built into the mirror and the turning mechanism to guard against icing.

10. The remainder of the equipment will be housed in a building at the foot of the tower. A rack will contain the transmitter and receiver unit, the modulator, the synchroniser units, power packs and monitoring equipment to assist in checking the equipment and assisting rapid localisation of any fault.

11. In the same room will be a display console containing five plan displays and the controls necessary to operate the whole equipment (an artist's impression of this consule is shown in Fig. 2). The first display will show a small-scale view of the whole of Liverpool Bay, the remaining four will each show a large-scale view of some part of the Channel. These latter displays are of a new type which show a precision picture in the limited arc and range interval which it is desired to inspect, and show a true plan presentation. The four displays will be set up to the same natural scale and will slightly overlap one another in range, so that an uninterrupted view of the area, much larger in size than could be accommodated on a single cathode ray tube, is given. Each tube will have a chart in front of it of the appropriate part of the Channel, with all buoys and other navigational marks plainly indicated so that identification of echoes from these objects is rapid and unmistakable. A rectangular grid on each display enables the grid reference of any echo to be read off directly and the reference can be plotted readily on a chart with the same standard rectangular grid marked on it. The position of any vessel can thus be fixed more quickly than would be possible if range and bearing strobes were used and if range and bearing had to be plotted on a chart before the fix could be made. The grid reference can be communicated directly to any vessel requiring a fix without the necessity for previous plotting on the chart. Throughout the design, circuits have been chosen which are well suited to the eventual transmission of information over a radio link system to remote displays, and this facility can be added at a later date without modifying the equipment already installed.

12. In an adjoining room of the same building will be installed

the Harbour Authority's W/T and R/T communication equipment, with provision for remote control from the position of the display console. The same building will also contain living quarters for the Operators. Motor alternators to provide A.C. power from the normal dockyard D.C. supply are mounted in a separate building near by and a stand-by diesel generator provides against possible failure of the main supply.

Operation

13. The equipment will be operated by the existing three R/T Operators, who will first receive instruction in radar operation. Intelligent practical use increases immeasurably the results obtainable and only with constant practice will the full efficiency of the installation become apparent.

14. Later the number of Operators will be increased to six, when two Operators on continuous watch will provide a twenty-four-hour service.

Assessment of Value to Port Authorities

15. Within the limits of its geographical setting, a port will attract vessels only in so far as it can offer safe approach, safe entry and departure, safe anchorage and good access to docking accommodation; and it is the plain duty of the Port Authority, in its own interest, to make available the best facilities within its power. Successful administration of a dock system is reflected in ship turn-round times, which, to the shipowner, may represent the difference between the financial success or failure of a voyage. Thick weather can neutralise the best port facilities and it is in such conditions that a harbour radar installation will be of most value.

16. Some of the direct uses of shore radar to a Port Authority include the following:-

(a) at Category 1 ports the Authority will maintain a large number of floating navigational marks; these marks, which (in heavy weather) are subject to displacement and may then constitute a danger to shipping, require considerable maintenance and continuous observation to ensure efficient lighting and tenure of exact station. At Liverpool this requires the services of a tender and staff at periodic intervals entending over a considerable part of the year. Shore-radar will provide an all-weather means of observation and a few minutes daily observation of these marks will dispense with the services of the tender for this duty with considerable economy to the Port Authority.

(b) Again at Liverpool, Lightships are used primarily as navigational marks to provide lighting and fog signals and also as look-out stations. With the introduction of shore radar, two of these Lightships will be abolished and replaced by unwatched Lightships, providing the necessary navigational warnings, and their function of a look-out station will be replaced by shore radar. A considerable economy to the Authority will accrue.

(c) The Port Authority's official responsible for docking operations will be accurately informed as to movement and progress of vessels entering the port, and dock movements will be regulated on this information.

17. Some indirect uses of the installation are:-

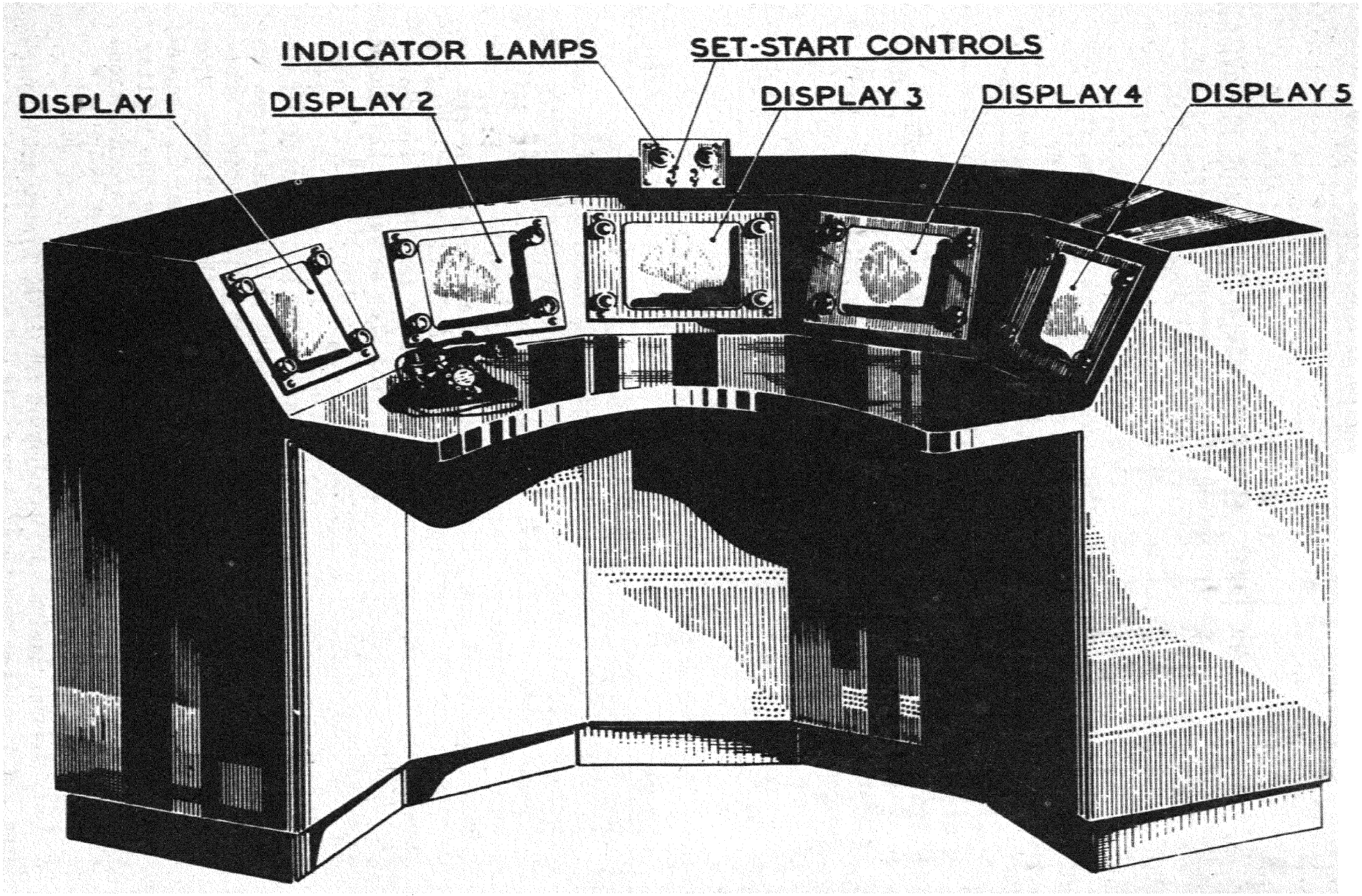
(a) Entry of a vessel into a Category I port necessitates navigation in certain phases and under varying conditions. Landfall at the seaward approach to the Port can be assisted materially by information from the shore radar, particularly in thick weather. The position of the Lightship and the position of the Pilot Boat, if a Pilotage Station be there established, can be given and, conversely, information as to the vessel's arrival and position can be afforded to the Pilot Boat. Before entering the Channels, particularly in thick weather, a Pilot or Master requires to know what vessels are navigating or are at anchor during the passage of his own vessel through these Channels. This information can be rapidly and accurately transmitted to the Pilot, thus enabling him to enter the Channels with confidence and to avoid being delayed outside until improvement of weather takes place. A saving of time will be effected and thus improve the attractions of the port to the shipowner.

(b) Similarly, when a vessel occupying a berth in the River or Anchorage requires to dock in thick weather the Pilot will desire to know the state of the River or Anchorage with regard to shipping before leaving his Anchorage berth; conversely, vessels undocking can be similarly assisted.

(c) Before finally leaving the port, vessels calibrate their directional wireless on an established

calibration station situated within the port area. This calibration must take place in an accurately defined position not less than two miles from the station. In conditions of poor visibility, vessels are unable to determine with sufficient accuracy their exact position relative to the Station. This can be determined by shore radar and the information transmitted to the vessel.

(d) In isolated cases shore radar may observe that a vessel is standing into danger when approaching or navigating it within the area of the port. This may be caused by an inaccurate landfall of the port and the missing of outer navigational marks. Known cases of strandings at Liverpool during the last few years may well have been avoided by the use of shore radar.



PROPOSED CONTROL CONSOLE
FIG. 2.

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LANAC: A COMPREHENSIVE NAVIGATION AND ANTI-COLLISION SYSTEM

- By -

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ABSTRACT

This paper describes a combined aeronautical and marine navigation, anti-collision, traffic-control, and rescue system employing two basic types of radio-aid equipment: a "challenger" and a "replier". The challenger, a postwar version of the interrogator-responsor used in military Identification, Friend or Foe systems, is carried aboard all craft and serves at traffic-control stations on the ground. The replier, a postwar version of the IFF transpondor, likewise is carried aboard all craft, and also serves on the ground as a beacon.

As in IFF, the major functions of the LANAC System depend on the automatic transmission of Morse-coded pulse signals from the replier, at one point, to the challenger, at another point, whenever the replier is "triggered" by pulses from the challenger. Upon reaching the challenger, these Morse-coded signals appear on a scope-type indicator, there serving to locate and identify the replier that transmitted them. The challenger also serves as a conventional radar when necessary.

Several marine applications of the LANAC System are enumerated and discussed, emphasis being laid on the advantages of the automatic-identity feature. It is shown that challenger-replier operation affords greater operating ranges than radar with relatively small equipments that require less power than equivalent radar sets.

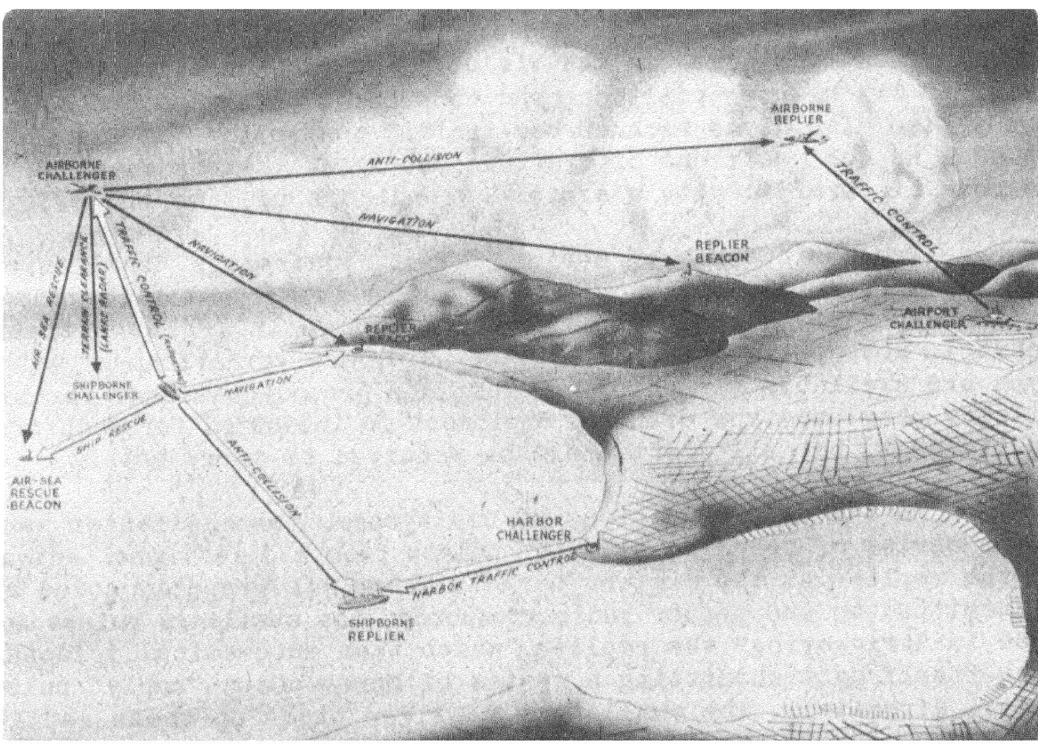
LANAC: A COMPREHENSIVE NAVIGATION AND COLLISION-PREVENTION SYSTEM

Introduction

1. LANAC--which stands for LAminar Navigation and Anti-Collision--is a comprehensive navigation, anti-collision, traffic-control, and rescue system utilizing 1000-Mc, low-power, pulse transmitters and receivers with associated scope displays to permit the safe and expeditious movement of vessels and aircraft alike under all weather conditions. Developed and tested by the Hazeltine Electronics Corporation of Little Neck, L.I., N.Y., LANAC is a commercial outgrowth of the Identification, Friend or Foe (IFF) systems used for the rapid identification of friendly ships and planes during the war, and as such it affords the automatic identification of all cooperating craft and beacons as one of its leading advantages.

2. LANAC's specific applications in the maritime service include precise coastwise and channel navigation, harbor approach, all forms of collision prevention, harbor-traffic control, traffic reporting, sea and air-sea rescue, and high-seas danger-area location marking. Most of these applications are represented in Figure 1.

Fig. 1. Major Functions of the LANAC System.



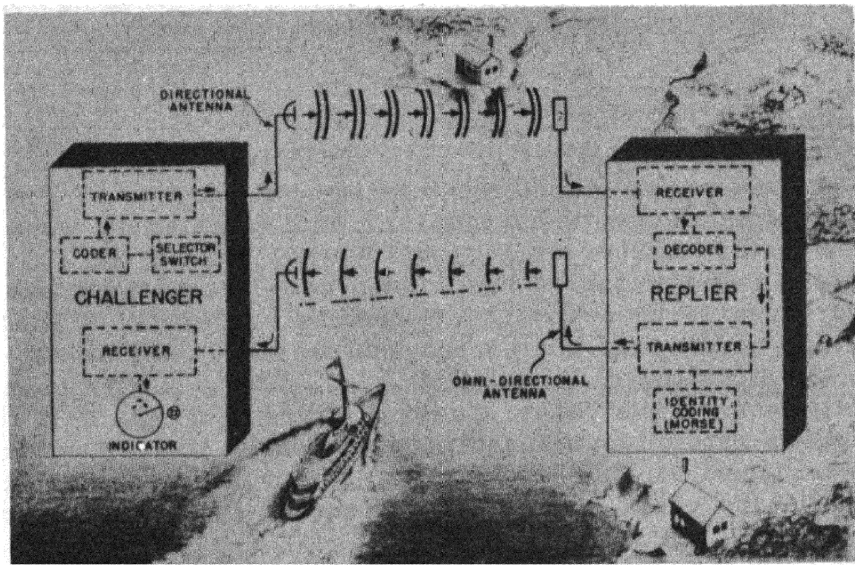


Fig. 2. Block Diagrams of the LANAC Challenger and Replier.

System Fundamentals

3. LANAC performs its major functions through an automatic interchange of position and identity data between moving craft, beacons, and traffic controllers. In typical maritime use the system gives each ship the location and identity of all beacons, craft, and important obstacles in the vicinity, thereby enabling the navigator to fix his own position, and to proceed safely on his course. The system also gives each harbor-traffic controller the identities as well as the positions of craft in the area, thereby enabling him to move his traffic with a minimum expediture of time and effort.

4. Two basic types of equipment are required: a "challenger" (a transmitter-receiver known in IFF as an interrogator-responsor) and a "replier" (a receiver-transmitter known in IFF as a transpondor). Both operate in the 1000-Mc band, and variations of either type are available for ship, aircraft, or ground stations. For simplicity only one type of LANAC equipment is indicated for each craft in Figure 1, but all craft would be required to carry both.

5. In the major functions of the system, the challenger sends out a series of coded "challenge" pulses from a directional antenna to the replier at the distant target. There, if properly coded and transmitted on the proper radio frequency, the challenge pulses succeed in "triggering" the replier, which then automatically identifies itself by transmitting a series of Morse-coded "reply" pulses in all directions. The challenger receiver picks up these replies

and feeds them to a display console where the target's distance, direction, and identity are instantly shown to the operator.

6. The target's range is determined by measuring the elapsed time between the instant that a pulse leaves the challenger transmitter and the instant that the corresponding reply pulse returns to

Fig. 3. Use of LANAC in Coastwise Navigation.

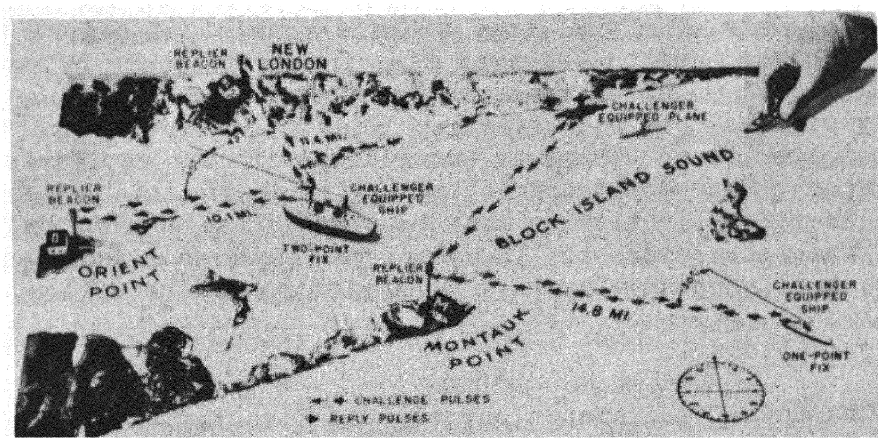
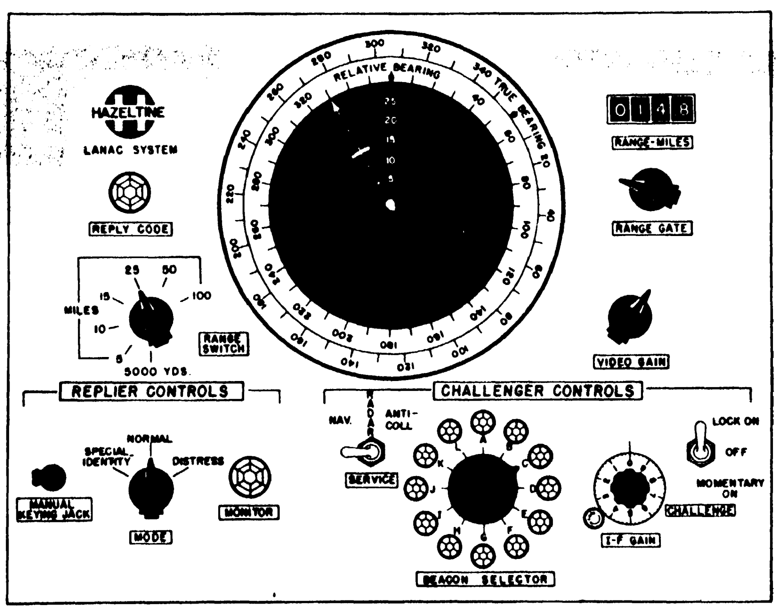


Fig. 4. Shipboard LANAC Control Console.



the challenger receiver. Since this measurement is based on the constancy of the speed of transmission of electrical energy, the accuracy can be made less than one percent of the range. Relative bearing is provided in the usual manner by the challenger's directional antenna. True bearing also may be obtained by coordinating the challenger's display system with the craft's gyro compass.

7. Block diagrams of the challenger and replier appear in Figure 2, which also illustrates the characteristics of the challenge and reply signals. The challenge signals consist of paired radio-frequency pulses, and the elapsed time in microseconds between the first and second pulse of each pair determines the challenge code. The reply signals consist of single pulses, some of which are "wider" (more prolonged) than others in accordance with the replier's Morse identity code. Separate transmitting and receiving antennas are represented in this illustration only to clarify the operational functions of the two equipments. In actual practice, each equipment uses a single, small antenna for both transmission and reception.

Data Presentations

8. The target's distance may be read directly on the challenger's scope, or on a convenient meter that repeats this data for any one target desired. True and relative bearing also appear on the scope, if a PPI is used; other types of scopes require antenna-bearing indicators. Groups of either three or four Morse letters--repeated over and over again as long as the replier is being triggered--are presented in blinker by a flashing lamp to identify the target, and each of these coding sequences requires, accordingly, 10 or 12 seconds for completion. The Morse can also be aurally presented.

Lanac and Radar

9. It is obvious that LANAC has much in common with radar, both systems employing pulse-type signals, directional antennas, and scope type indicators. In one function of the LANAC system (described later) challengers actually serve as radars. The distinctions between radar and LANAC are, however, greater than their similarities.

10. First of all, LANAC uses two radio-frequency channels in the exchange of challenge and reply, thus eliminating confusing sea and land-mass echoes from the display, and improving the efficiency of the equipments themselves by lessening the transmitter-receiver interaction within the individual challenger or replier.

11. Since target echoes are not utilized in challenger-replier operation, the transmitting power required is greatly reduced. Line-of-sight LANAC ranges of 20 to 50 miles can be obtained in normal

marine applications with 1500- to 10,000 watt transmitters, whereas comparable radar performance demands 1,000,000 watts. (The shortest range LANAC can measure accurately in about 300 yards.)

12. Furthermore, since the challenge pulses are coded so that only selected repliers can decode them and answer, unwanted replier signals do not clutter the display. In marine LANAC as now proposed, all ship repliers operate on a common pair of transmitting and receiving frequencies, and are set to answer only one challenge code, but replier beacons are set individually for different combinations of frequencies and challenge code. Thus, the ship replier serves dually in the system's anti-collision and traffic-control functions without "jamming" the scope of a navigator who is taking a fix on a beacon; likewise, when navigational beacons are worked, the scope is not cluttered with signals from more than one replier in each vicinity where two or more beacons are stationed close together. Sufficient challenge codes are available so that, if necessary, one pair of frequency channels alone can accommodate all of the marine LANAC functions--including navigation, anti-collision, traffic-control, etc.

13. But LANAC's most useful distinction from radar is the automatic-identity feature. Although present-day radar beacons employ identity coding, radar affords no identity data on any other kind of target. The reflected echo from a radar-detected object may tell an operator where that object is, even what it is, but never who it is.

Lanac Navigation

14. LANAC, in its marine navigational functions, is especially suited to coastwise navigation, channel navigation, harbor approaches, and all other work requiring precise, close-range fixes. The system also will extend usefully to long-distance marine navigation if permanently located weather ships, stationed in the open sea, are equipped with repliers. Figures 3 and 5 show how LANAC replier beacons can serve at strategic points where all-weather aids to navigation are particularly needed.

15. The LANAC two-point fix is extremely accurate, since it is based entirely on the intersection of two precisely measured distance circles, and does not depend on antenna-bearing data. Directional antennas need serve, in fact, only to resolve ambiguities in any LANAC two-point fix. The LANAC one-point fix is not as accurate as the two-point fix, since a plot of the vessel's position then is half dependent on an angular measurement, and hence on the beam width of the challenger's antenna. One-point LANAC fixes are accurate enough for most practical purposes, however, since directional antennas having narrow beam widths can be supplied.

16. The operational procedure involved in taking a one-point fix necessitates approximately four or five manipulations with a set of controls on a console like the one in Figure 4. For example, the fix on the Montauk beacon portrayed in Figure 3 would require the following procedure at this console: (1) The SERVICE switch is turned to NAV. This clears the display scope of all signals from repliers on other craft (or radar-type echoes if the switch was previously set to RADAR). (2) The BEACON SELECTOR is set at "C" (assuming that "C" designates the challenge-code and radio-frequency combination on which the Montauk beacon operates). (3) The CHALLENGE switch is turned ON. The challenger now delivers its signals, and a reply from the Montauk beacon appears at the correct range and azimuth on the PPI display. (The foregoing procedure assumes the use of a continuously rotating directional antenna. Small-size antennas of this type, about 30 inches overall, have been designed.) (4) The PPI azimuth cursor is aligned with the reply pulse, and the exact true and relative bearings of the beacon are observed. (5) The RANGE GATE control is adjusted until a "moving-range spot" coincides with the observed reply pulse, then the beacon's exact distance is read on the RANGE --MILES meter; the beacon's Morse identity code is read in the REPLY CODE lamp.

17. To obtain a two-point fix, the BEACON SELECTOR setting is changed as required, and steps 4 and 5 above are repeated for the new reply signal. Step 5 may be entirely omitted if an "A"-scope display is used in conjunction with the PPI--as recommended for large vessels. With this combination both distance and identity can be read directly on the "A" scope, bearings on the PPI.

Anti-Collision

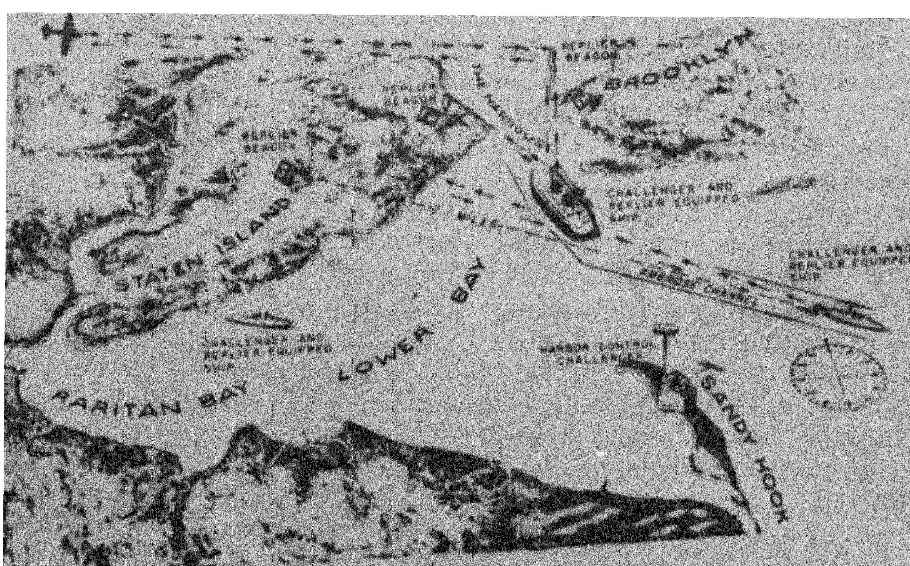
18. With the SERVICE switch at ANTI-COLL., and the CHALLENGE switch at LOCK ON the shipboard challenger affords continuous collision warning in traffic-laden channels or harbors by locating other nearby vessels on the basis of their replier signals. The shipboard challenger also warns the navigator of reefs, shoals, and small islands where small, battery-operated, hazard-beacon repliers are installed. (Such hazard beacons also can be used as aids to navigation.) In the anti-collision (and traffic-control) service the signals from all repliers within range (except the exclusively navigational beacons) appear on the scope at once. When the challenger is not equipped with an "A" scope and the navigator requires the identity of a particular target picked up, he can obtain this information by setting his PPI azimuth cursor and adjusting his RANGE GATE control without loss of other targets from the PPI screen. Sector scanning as used in wartime IFF, when the rotating antenna was stopped and held in the direction of the target, is unnecessary.

19. The challenger also can operate as a conventional radar, thus affording collision protection when such obstacles as icebergs, floating hulks, fixed hazards or other vessels without repliers are concerned. By setting the SERVICE switch at RADAR, the challenger's transmitter and receiver both operate on the same radio frequency, and the challenger then becomes a radar--locating inert objects by picking up the echoes of its own transmitted pulses. This cuts the challenger's range to about 10 or 15 miles, but still provides sufficiently early warning to permit most ships to avoid the obstacle. A challenger with one transmitter and two receivers is recommended for large vessels so that radar-type echoes can be displayed on one scope, and replier answers on another, at all times.

Harbor-Traffic Control

20. Harbor-traffic control, an ever-growing necessity at busy, fog-bound ports like San Francisco, London, and New York, is one marine service in which LANAC should prove especially useful, for in this case the importance of ascertaining ships' identities supersedes even the need of learning their exact positions. The harbor controller cannot route his traffic until he knows where on the priority list each vessel stands, and this knowledge of course, entails identification as a major pre-requisite. LANAC is offered to the harbor-traffic control service as an automatic radio-location system combined with a high-speed communications system, for with both a PPI and "A" scope installed at his shore-based challenger, the controller always has before him an up-to-the minute "chart" of the vessels in his area and a continuous indication of all these vessels' identities.

Fig. 5. LANAC Channel Navigation and Harbor-Traffic Control.



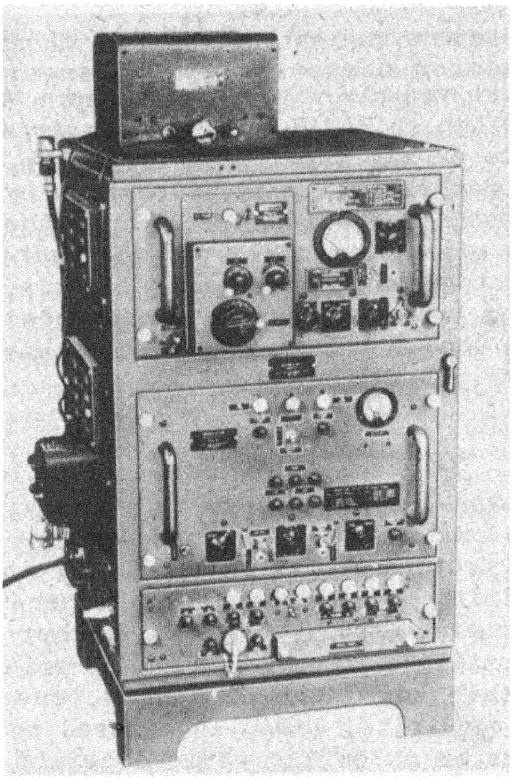
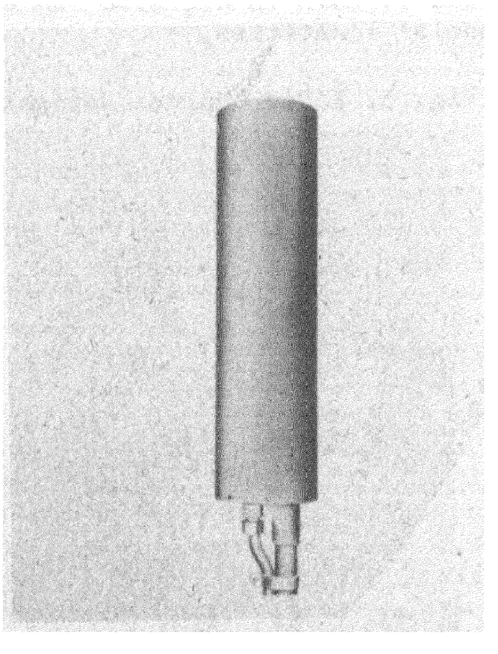


Fig. 6. LANAC High-Power Beacon.

Power output 10,000 watts; power consumption, 1000 watts; weight, 500 pounds; space requirements, 23.2 cubic feet.

21. The LANAC communications feature is not confined to simple identity, as provisions are made for hand keying of the ship's reply signals whenever the necessity for any other kind of replier message arises. This is the purpose of the MANUAL KEYING JACK on the display console in Figure 4. Furthermore, if the replier's MODE control is turned to SPECIAL IDENTITY, the replier will transmit a distinctly different type of pulse signal that can be interpreted instantaneously, without any scope adjustments, at the distant challenger's PPI—a signal that can be employed for many practical applications. For example, if a harbor-traffic controller needs to learn which ships on his display are vessels of certain foreign registry, he does not have to check each vessel's Morse-identity letters individually against a master "call" list; he can broadcast a general order through voice or radiotelegraph communication channels commanding all of such vessels to set their repliers for special identity. Distinctive signals from all ships of this registry then would appear on the controller's PPI at once, the necessary information from all of them being gained in the same length of time required to querv one vessel alone.

Fig. 7. Antenna for Beacon in Fig. 6.



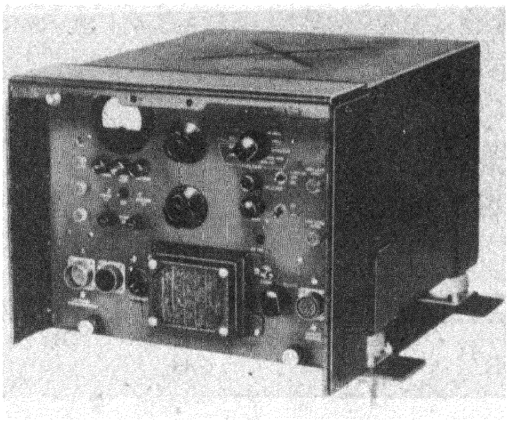


Fig. 8 LANAC Medium-Power Shipboard Challenger.

Power output, 1500 watts; power consumption, 275 watts; weight, 155 pounds; space requirements 9.25 cubic feet.

Traffic Reporting

22. The high-speed communications feature of LANAC equipment enables ships in the open sea to exchange traffic reports automatically with passing vessels and trans-ocean aircraft. For example, a challenger-equipped ship can challenge and identify a replier-equipped aircraft, then report the plane, or the aircraft navigator can take a fix on a replier-equipped ship with his own challenger, identify the ship, and thereby obtain a rough check on his position and flight progress.

Rescue

23. For rescue work, all LANAC ship and aircraft repliers are capable of transmitting distinctive signals that indicate distress, and small, portable repliers--weighing less than 30 pounds--are used as rescue beacons on lifeboats or rafts. The distress signal has the same meaning as an SOS, and is received by all ship, shore, and aircraft challengers within range. It appears on the scope as a set of five "pips" closely spaced together--the fifth "pip" of the set blinking on and off in Morse to identify the sender. Distress operation is automatic, like all other replier functions, once the MODE switch on the craft's LANAC console has been set to DISTRESS. The rescue beacons enable searchers in ships or planes to "home" directly on a speck in the ocean that neither radar nor the naked eye can see except at very close ranges.

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ALL-WEATHER NAVIGATION WITH DME

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ABSTRACT

This paper describes a system for all-weather, short-range marine navigation suitable for use by small, as well as large vessels. The equipment requirements are a challenger (radio transmitter-receiver) installed aboard ship and several replier beacons (receiver-transmitters) located around harbors and at strategic points along the coast. Range to a beacon is determined by measurement of the elapsed time between the instant a challenge signal leaves the ship and the instant a beacon reply signal is received by the ship. Range to the beacon in use and its Morse-coded identity are displayed on a direct-reading distance meter. Positive identity of the source of a beacon reply is assured by the frequency and coded characteristics of the signals exchanged between ship and shore. The beacon is automatic in operation, while the semi-automatic operation of the challenger is simple and rapid. In addition to its navigational uses, portable beacons carried in lifeboats and rafts enable DME to be used in air-sea rescue.

System Fundamentals

1. The Hazeltine DME (Distance-Measuring Equipment) System utilizes low-power, pulse transmitters and receivers with associated meter displays to simplify the navigation of vessels and aircraft alike under all weather conditions. A commercial outgrowth of wartime IFF (Identification, Friend or Foe), this system provides the navigator with an exact, continuous indication of his range from a self-identified beacon. The maximum range of this system is line-of-sight (accurate to plus or minus one percent of the range). The minimum range is zero yards.

2. The basic DME system, as illustrated in Figure 1, consists of a radio transmitter-receiver, called the challenger, installed in a ship and a radio receiver-transmitter, called the replier, installed on the shore. The challenger initiates the sequence of events by continuously transmitting a stream of coded radio-frequency pulses in all directions from its omni-directional antenna. The challenging signal is received by the DME replier beacon and a decoder unit in the replier determines whether to accept the challenge. If the code of the challenging signal is the code for which

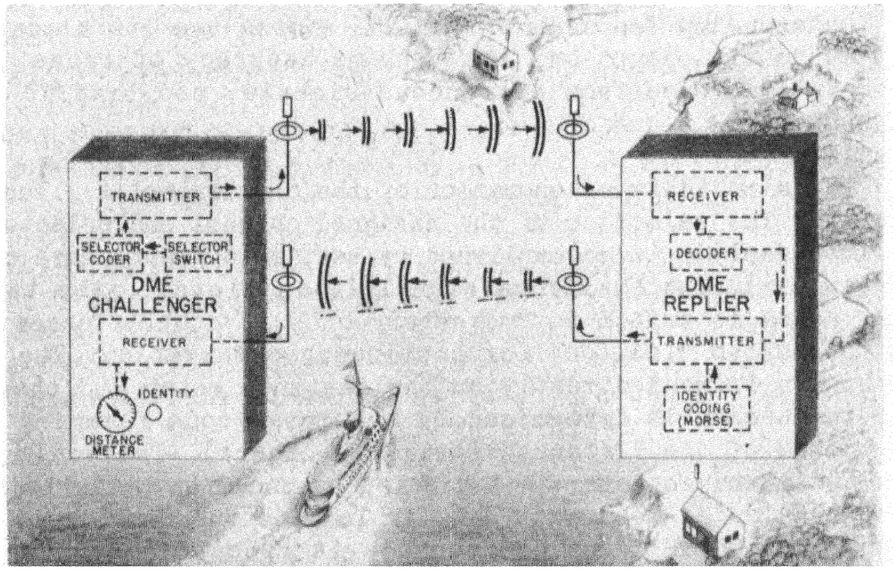

Fig. 1. Functional Diagram of Hazeltine DME Navigational System.

Range to the shore beacon is determined by elapsed time between the instant the shipborne challenger sends a challenge signal and the instant it receives the beacon reply signal. Reply signal is Morse-coded to show identity of beacon.

the replier's decoder is set, the replier accepts the challenge and transmits a reply. The reply is a stream of radio-frequency pulses which carry the beacon identification letters in Morse code. The reply is received by the challenger and provides information for the display of the range and identity of the beacon on the challenger distance meter. Ranges are obtained by measuring the elapsed time between the instant that a pulse leaves the challenger's transmitter and the instant that the corresponding reply pulse reaches the challenger's receiver.

3. Figure 1 also indicates the characteristics of the challenge and reply signals. The challenge signal consists of paired radio-frequency pulses and the elapsed time in microseconds between the first and second pulse of each pair determines the challenge mode. The reply signal consists of double pulses and the Morse identity code is arrived at by interrupting the radiation of the reply signal for intervals corresponding to the dots and dashes of a preset three or four letter beacon call sign. Separate transmitting and receiving antennas are shown in this figure for clarity only. In practice, all challengers and repliers have common antennas for transmission and reception, duplexing circuits being utilized to protect the receivers while the transmitter is operating.

Outstanding Features

4. Outstanding features of the DME system are its almost completely automatic operation, its extreme accuracy of range, freedom from interference from extraneous signals, and traffic handling capability.

5. The simplicity of operation of the challenger is illustrated in Figure 2. The selection of the assigned channel and selector code for a given replier is accomplished by setting a front panel control knob (step one). The challenge signal is initiated (step two) by throwing a toggle switch to "momentary on", if a brief observation is desired, or to "lock on" for continuous observation. The range to the beacon is read directly on the distance meter and the identity of the beacon is determined by the Morse code flashing light at the bottom of the distance meter (step three). The scale to be read on the distance meter is indicated by one of two lights flanking the Morse code flashing light. As long as the replier is being challenged the Morse identity sequence is repeated over and over again, each sequence requiring 10 or 12 seconds, depending on whether three or four Morse letters are used. (The necessary design and development has been completed for inclusion of aural monitoring of the identity signal at the challenger in those installations where this feature is desired.)

nals from the challenge pulse, nor the challenge pulse itself can cause erroneous readings on the distance meter. There is no possibility of a reply being received from any but the desired beacon because the beacons in a given area operate on different frequencies.

9. The traffic-handling capacity of the system is considerably enhanced by the relatively low reply repetition frequency and the character of the reply which it is able to use with successful display. For example, upward of 50 DME challengers are able to obtain reliable signals from the same beacon, as compared with a practical limit of around four or five search-type radars simultaneously "searchlighting" on the range-coded microwave beacon of present design.

Applications

10. In operation, the DME system requires the installation of several replier beacons at harbor entrances, channel entrances, and at strategic points along the coast. Ultimately the system could be expanded to completely equip the coast so that two beacons would always be within range. For coastal navigation, Figure 3 illustrates a two-point fix obtained from beacons located on Long Island at Montauk Point and Orient Point. The ambiguity encountered due to the two-place cross-over point can be resolved by inclusion of dead reckoning information in the problem or by antenna directivity of a low

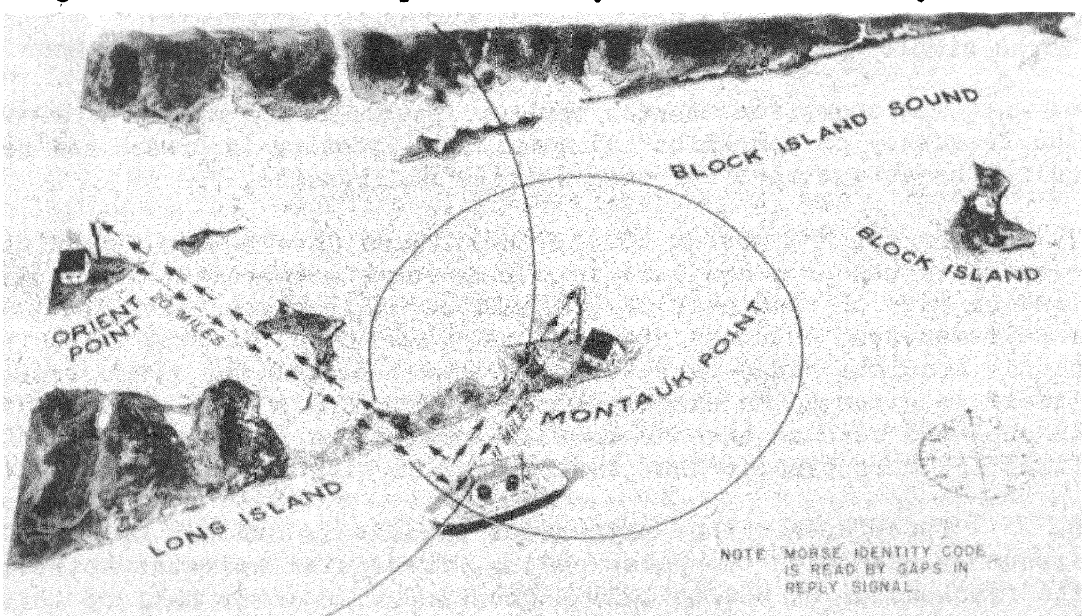

Fig. 3. A Two-Point Fix Obtained in Typical Use of DME for Coastal Navigation.

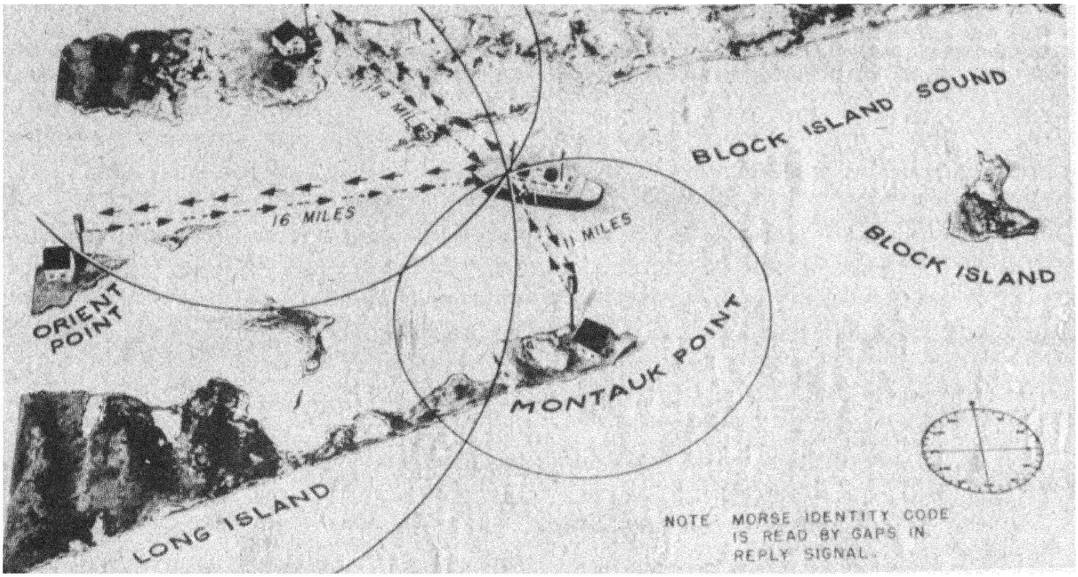

Fig. 4. A Three-Point Fix Obtained in Typical Use of DME for Harbor Approach or Navigating Restricted Waters.

order. For harbor approach and navigation in restricted waters more numerous beacon locations afford highly accurate three-point fixes. Figure 4 illustrates an approach being made to New London, Connecticut, using ranges from beacons located at Montauk Point, Orient Point, and New London. The extreme accuracy of the ranges obtained to points of positive identity and the speed and facility with which observations are made make this system ideal for navigating restricted waters in any kind of weather.

11. DME repliers installed in weather ships stationed at specified positions near the trans-ocean sea lanes would serve as convenient navigational aids when fixes using celestial observations cannot be made.

12. Employing a hand- or battery-operated replier emitting a characteristic emergency signal, the DME system can be used in air-sea rescue. The use of the hand-powered model in guiding a ship and airplane to a lifeboat is shown in Figure 5, while an aircraft dropping the battery-powered model in the vicinity of a liferaft is shown in Figure 6. On receipt of an emergency signal the navigator would know there was a craft in distress on some bearing from him at the range at which the contact was made. He would immediately start a dead reckoning track and continue on his course for a sufficient time to allow the range to the raft to change. A range ring drawn from his dead reckoned position at that time would cross with

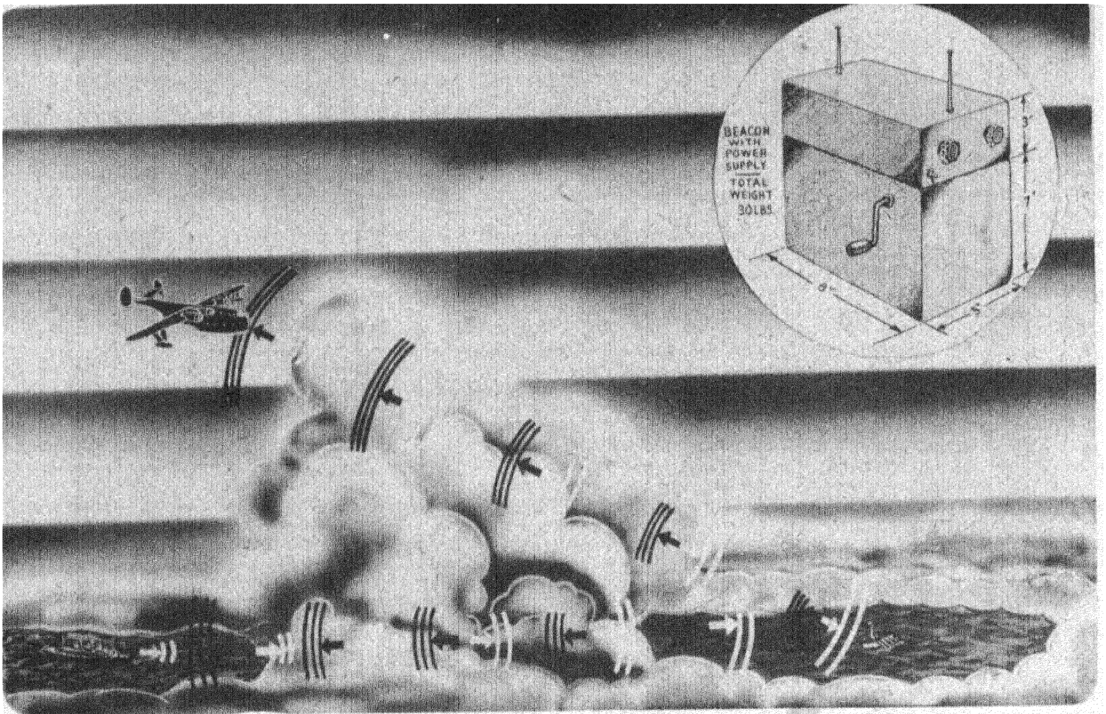

Fig. 5. Air-Sea Rescue of Lifeboat Equipped
With Hand-Powered DME Beacon.

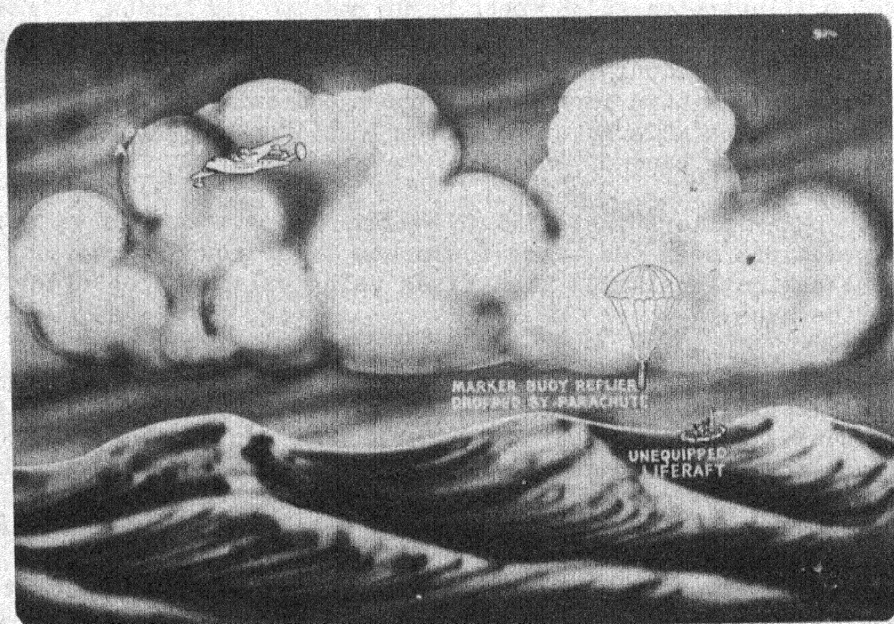

Fig. 6. Battery-Operated DME Beacon Dropped in Vicinity
of Liferaft for Air-Sea Rescue.

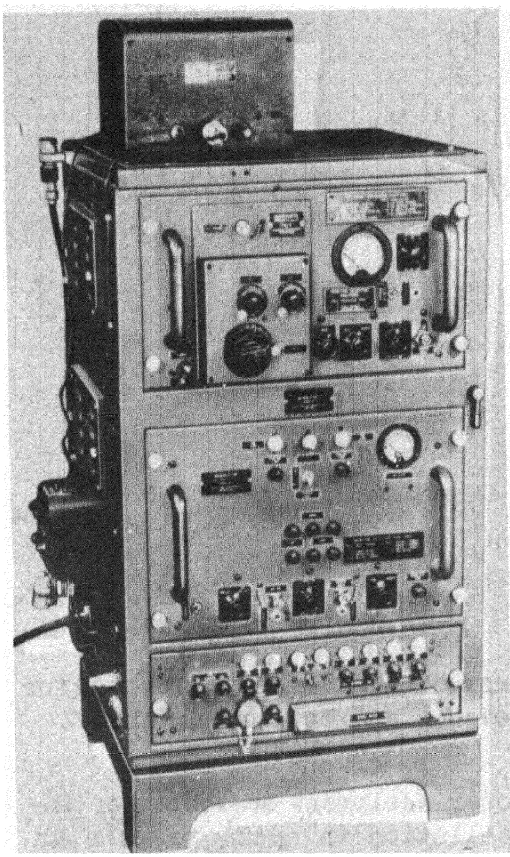

Fig. 7. DME Beacon.

DME System requires beacon installations at harbor entrances, channel entrances, and along the coast.

the contact-range ring drawn at the time he started the track. The two-place cross-over points would give him a choice of two positions to head for. He would elect one and a closing range would then verify the accuracy of the choice he made. Should the range open, he would simply have to reverse course and head for the position indicated by the second cross-over point. Here again, antenna directivity of a low order would simplify the operation.

13. The Hazeltine DME system for air navigation was operationally demonstrated at the conference of the Provisional International Civil Aviation Organization (PICAO) in October 1946, at Indianapolis, Indiana. There the reliability of the system characteristics and of the equipments themselves was well established; production contracts have been let, since, for the initial procurement of 1000-Mc DME beacons for airway installations. Since aeronautical and marine DME equipments all operate in the 1000-Mc band, coastal DME beacons can serve planes and ships alike.

14. It is feasible to include in all DME challengers an automatic direction-finder attachment so that bearing information as well as range information can be provided.

15. Front-view photographs of a challenger and a beacon are shown in Figures 7 and 8, respectively. The challenger, installed

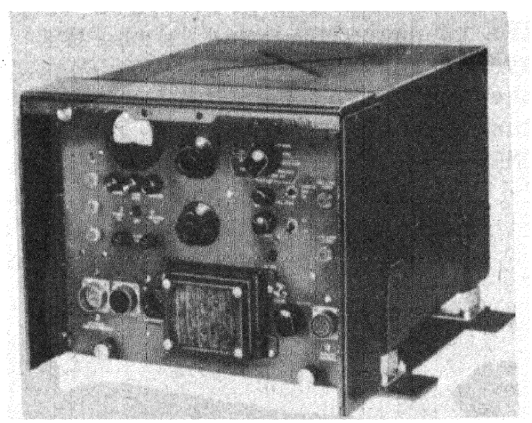

Fig. 8. DME Challenger.

Small, low-power equipment, installed aboard ship.

at any convenient location aboard ship, is remotely controlled from the control unit (shown in Figure 2) which is installed in a location convenient to the navigator. Installation requirements of the replier are limited only by a reasonable length of cable run to the antenna and the convenience of a suitable power source for the equipment. The antenna shown in Figure 9 is used for both challenger and replier installations. The antennas must be mounted on a mast, pole, lighthouse, or other high structure so that they are clear to radiate in all directions. Since the ranges obtained from the DME are line-of-sight ranges, the higher the antenna is mounted the larger will be the coverage area of any given challenger or beacon.

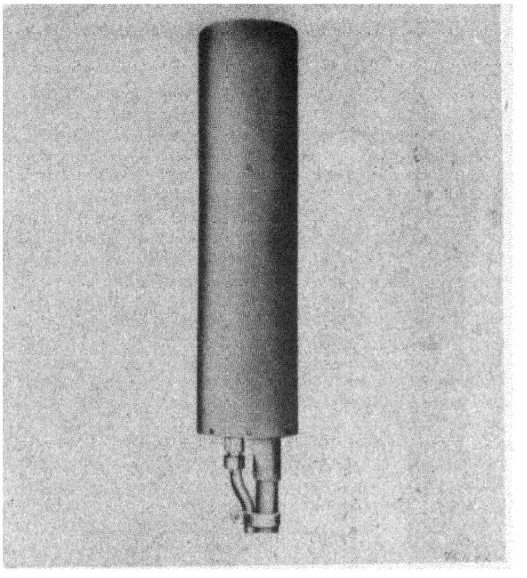

Fig. 9. DME Antenna.

Omni-directional antennas used for beacons and challenger alike.

Conclusions

16. IFF equipment was highly successful for use in aircraft and ships during the war. The application of the principles of IFF to peacetime uses in the DME system is a logical step because they are based on research work that has proved to be sound. The DME challenger is a small, low-power equipment suitable for installation in small vessels on which the expense of high-power electronic equipment is not justified. Installed in large vessels, it would be a dependable aid in navigating ships that cannot afford to be delayed by low visibility. In conclusion, Hazeltine DME at 1000 megacycles has been designed, developed, and tested and is available for use now.

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Navaglobe and Marine Navigation

By

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ABSTRACT

This paper first describes the marine applications of Navaglobe, which is a radio navigation system designed primarily for long range transoceanic air service. The usefulness of the system in the transitional zone, guiding surface ships from a moderate distance at sea to a point within the range of more accurate and comprehensive short range navigation facilities, is discussed. It is shown how Navaglobe may provide this service with certain economic and operational advantages. Also, the possible long range marine use of Navaglobe, and the possibilities of a "fine" version of Navaglobe, are mentioned. The second portion of the paper outlines the general considerations underlying the planning of a long range radio navigation aid and describes the general features and technical principles of the Navaglobe System.

NAVAGLOBE AND MARINE NAVIGATION

1. Applications of Navaglobe for Marine Navigation

a. Introduction

It is the purpose of the present paper to note how the Navaglobe radio navigation system, under development as a long distance aviation aid, may also provide useful services for marine use.

Work on an experimental model of a Navaglobe installation is currently in progress; indications are that installation of the transmitter and first experimental trials of the system may be begun towards the end of 1947.

At the present time, therefore, no experimental data on performance can be given. Various studies, however, indicate that the accuracy of the system, when perfected, may be expected to be one degree in the bearing of the receiver from the ground station. It is a characteristic of all bearing-type systems that the lateral accuracy increases proportionately as one nears the ground station. A fixed angular accuracy of one degree corresponds to lateral accuracies as next tabulated.

Distance from Ground Station	Lateral Accuracy
300 miles	5.1 miles
200 miles	3.4 miles
100 miles	1.7 miles
50 miles	1500 yards
25 miles	750 yards
10 miles	300 yards

b. Transitional Zone Guidance

The primary purpose of Navaglobe is to provide aircraft with a radio navigation service that is extremely reliable under all conditions, up to a maximum range of about 1500 miles from ground stations. That maximum range has been arrived at from a study of available land sites over the globe, and will allow all oceanic and polar regions to be provided with radio navigation service. Such service is highly desirable for air use in view of the known practical limitations of celestial navigation and dead reckoning procedures on board airplanes.

In marine service there appears to be a distinct need for an all-weather navigation aid that is reliable, convenient and quick-reading, in the transitional zone from open sea navigation to coast and harbor navigation. The function of the all-weather navigational facility in this transition zone is to lead the ship to a selected point within 10 to 20 miles of the desired landfall. Within about 10 - 25 miles of the ground station the accuracy of Navaglobe is about 300 - 750 yards, which is adequate for locating the desired point within the field of service of the short range aid with which the accurate final approach is made.

Navaglobe is an essentially unambiguous system; each reading is "fresh"; that is, it is conclusive and in no way dependent on unbroken continuity of indications registered cumulatively since some previous known position. Temporary interruptions of service from any cause - propagational, mechanical or human (at either the transmitter or the receiver end) - lead to no danger of ambiguity on resumption of the indications. And ambiguities in position are obviously more dangerous close-in than at mid-sea.

The above property of Navaglobe makes its service quite flexible. If two receivers are carried, for standby or other purposes, then, as is true in any system using essentially two receivers, complete fix information may be available at all times by keeping each receiver tuned to a different station so that intersecting lines of position are concurrently read on two indicators. In addition, however, either or both of the receivers may be temporarily and intentionally tuned in to other stations within range if it is desired to check one's position fix by reading additional bearings. Furthermore, if only one Navaglobe receiver is carried, or is available for use, conclusive, non-ambiguous fixes may still be obtained; one tunes it to two or more ground stations in succession to obtain (in a short time, without the complications of a running fix) two or more intersecting lines of position.

c. Long Range Use

A Navaglobe indicator might be a worthwhile equipment on board surface ships even for long range use, for times of protracted bad weather. In some cases it would give quite rough checks on DR positions; in many cases the accuracy would be comparable with DR. In any case, it would offer reliable service at all times, and in portions of the globe where other types of radio facilities might not reach, and this service would be conveniently presented and unambiguous.

It might be mentioned that the principles of a "fine" version of a Navaglobe type system have been worked out. Expected accuracies would be some six-fold better than that of the standard Navaglobe system so far discussed. The fine system would require a different type of ground station but the mobile installation would use the same receiver and indicator, plus some minor adapting equipment. A selector switch would allow readings to be made either on standard or on fine Navaglobe stations, as desired or as available. In the fine system the reading procedure would involve some complexity as a result of the procedure for ambiguity resolution. The reliability and range of the two versions would be the same.

2. Principles of the Navaglobe System

NOTE: The following is a condensation of a paper by the same authors on "Navaglobe - Long Range Radio Navigation System", published in the Proceedings of the National Electronics Conference, Vol. 2, 1946.

a. Distance Requirements

The first question that occurs when discussing radio navigation systems that are to be capable, ultimately, of covering all oceans, polar regions, etc., is just what distance range is required for the ground stations. One may assume that in order to give track guidance and also to give the possibility of establishing a fix by means of intersecting radio lines of position, an airplane must be within range of at least two ground stations whose lines of position cross at a usable angle; and that ground stations are to be located at actual land points, coastal or island, not on moored ships or man-made islands. Only after the distance of propagation has been specified can the question of reliability of service be discussed.

Accordingly, the disposition of the land masses on the earth was studied intensively by reference to existing maps and by consultation with the Hydrographic Office. It appeared that a reliable transmission radius of at least 1500 miles would be necessary to provide duplicate coverage of the important ocean regions of the globe from land-based stations. Figures 1, 2 and 3 show a possible pattern of stations which would achieve the result of duplicate coverage of the ocean regions all over the globe, except for the south polar region. Some 4 to 6 stations would be sufficient to cover the important North Atlantic area. Considerable flexibility of pattern was found to be possible except in the southeast Pacific region. No consideration was given to the stations required to cover the continental areas since it was clear that this

presented no difficulty. The only question considered was how small a working radius could be used while still insuring coverage of all traveled ocean regions.

As mentioned above, this study showed that a working radius of 1500 miles over sea water would be essential for a long range navigation system intended to be extended to all traveled portions of the globe. The study further showed that a total of somewhat less than 60 stations would suffice for covering all ocean areas. It was clear that only a few additional stations would be required for coverage for each continent, so that not more than 75 stations in all would be needed for complete coverage of the globe exclusive of the south polar cap.

b. Propagational Problems

For short distance applications high radio frequencies are preferred since sharp directive effects are obtainable with small transmitter installations. For medium range work, up to a hundred miles or so, certain frequencies may be preferred for practical reasons but almost any frequency would do. In both cases the power requirements create no great problem. For a 1500 mile reliable range, however, the question of proper frequency for reliable transmission is a critical one; and power, transmitter and antenna cost are not inconsiderable. An intensive review of all available data on propagation characteristics of various radio frequencies was, therefore, undertaken. This study was directed to the question of which frequencies could be relied on to propagate to a distance of 1500 miles over sea water 100 percent of the time. Needless to say, it was soon found that no radio propagation can be said to be 100 percent reliable. Nevertheless, after careful review of more than 100 published articles covering some 20 years, it was finally found that it is possible to achieve reliability in excess of 99 percent; but this is practical only through the use of low frequencies in the vicinity of 70 kilocycles per second and with extremely narrow bandwidths of the order of 10 to 20 cycles per second.

For long-range propagation only the lower frequency bands (LF and VLF) and the high-frequency band (HF) are suitable. Medium frequencies (MF), as used in broadcasting, have very short daytime ranges and are very variable at night; the very-high frequencies (VHF, UHF and SHF) are restricted to radio line-of-sight distances.

High frequencies, as used in short-wave broadcasting and communication, may travel along distances with comparatively little power and small antennas; however, interruptions and disturbances are frequent and serious, the ionospheric layers being very variable

with respect to these wavelengths. Fading is common; worse, at intervals that may be frequent and protracted, there are complete blackouts of reception connected in some way with magnetic storms and sun-spot activity.

Low frequencies, as used since early days for very long-distance communication, propagate quite steadily day and night, all seasons and years, the ionospheric layers which reflect them being less subject to upheavals. Also, one frequency serves for all directions, distances and times of transmission, while for long-distance communication using high frequencies a transmitting station often has to choose among three or more available frequencies to fit the circumstances. Low frequencies are especially useful for radio propagation in arctic and polar regions, where air traffic may be expected to increase in the future, to take advantage of direct great-circle paths. In these regions high-frequency transmissions are so excessively subject to ionospheric disturbances as to be practically useless except for short distances.

Thus, for the all-important consideration of reliable and uniform propagation, low frequencies seem indicated for long-range navigation systems. Long wave transmitters, however, require large antennas and considerable power. Also, the bandwidth should be extremely narrow, for two reasons: First, static, which may be very disturbing at low frequencies (less so in arctic regions, more so in tropical areas) may be reduced in effect by narrow-band operation. Secondly, the low-frequency band does not have room for many or wide channels; therefore, if a number of radio navigation stations are to be accommodated without interfering mutually or with other communication services, they must each take up very little channel space.

A summary of propagation studies[1] shows that frequencies between 15 kilocycles and 70 kilocycles are the best from the standpoint of reliable reception from a distance of 1500 miles with a given radiated power, taking into account the weakest signal propagation and the highest atmospheric noise level, but disregarding practical considerations of antenna cost and antenna efficiency. If the antenna efficiencies are taken into account and the antennas are limited to simple 2-tower flat-tops or single-mast umbrella loaded types with effective heights of the order of 300 feet, then it appears that the optimum frequency (i.e. the frequency giving a reliable 1500-mile working radius with the least

1. P. R. Adams and R. I. Colin, "Frequency, Power and Modulation for a Long-Range Radio Navigation System," Electrical Communication, Vol. 23; June, 1946.

power input to the antenna) is between 50 and 100 kilocycles. If it is desired to cheapen the antennas slightly at some increased cost in required input power, this study shows that the frequency may be raised as high as 125 kilocycles with only about 50 percent increase in required power.

On the assumption that the receiver bandwidths can be narrowed down to 20 cycles, it appears from the above-mentioned study that the input powers required for almost 100 percent reliability would be of the order of 7 kilowatts in northern United States and Canada, 25 kilowatts in the vicinity of New York, and 100 kilowatts for most tropical stations. These full powers, however, would be required only during certain days of certain seasons, so that the stations would normally operate with less than a quarter of the powers mentioned. The antenna efficiencies are estimated to be about 60 percent so that the radiated powers would be of the order of 4200 watts in Maine, 15 kilowatts in New York, and 60 kilowatts in the tropics during the worst seasons and a third or a quarter as much during other times.

It is estimated that except for a regular brief interruption of propagation lasting about 15 minutes at an accurately predictable time in the evening, the signal-to-noise ratio at a radius of 1500 miles would be sufficient for reliable operation approximately 99.9 percent of the time.

Fifty stations, enough to cover most ocean areas, and the North pole region, would not require more than a total bandwidth of 5000 cycles, without repeating the same frequency twice.

c. General Features of the Navaglobe System

For very long-distance service, systems which depend on directional patterns have a number of features of convenience. The single siting principle is used; lines of position are straight lines, or rather great circles, all leading to or from the ground stations, which may be located at or near important terminal points. Systems of this type have been used for limited radio navigation for a long time, the four course AN ranges being perhaps the prototype. The difficulty, however, is in devising a system which is not only propagationally suitable for the reliable 1500 mile range, (frequency, bandwidth) but which is also omnidirectional, direct reading, unambiguous, and which is economical in respect to antennas.

The Navaglobe system was proposed and is being developed for this purpose by the Federal Telecommunication Laboratories. It is essentially a low-frequency continuous-wave omnidirectional range

which is received on the airplane by a very narrow-band receiver equipped with a special azimuth indicator as illustrated at the left of Fig. 4. This narrow-band receiver makes use of a loop antenna, shielded to minimize the effects of precipitation static and cross-field corona static. Advantage is taken of the loop's directive pattern to provide additionally an automatic-direction-finder indication in the airplane, as illustrated at the right of Fig. 4. Both the azimuth-meter indication provided according to the omnidirectional range principle, and the bearing indication provided by the automatic direction-finder principle, are fully automatic. Thus, when the equipment is switched to a desired ground station, the indicators shown in Fig. 4 automatically turn to indicate either the azimuth of the airplane from the station, or the true bearing of the station from the airplane, respectively, depending on the position of the system selector switch.

As will be seen from Fig. 4, the azimuth meter is arranged to make two revolutions for 360 degrees. In Fig. 4, the pointer of the azimuth meter is shown as indicating an azimuth of 225 degrees. This represents the azimuth angle of the airplane as seen from the ground station. The true bearing from the aircraft to the ground station would be the reciprocal of this azimuth angle, namely 75 degrees. (This is true up to the point where convergence of the meridians matters.) Referring to the right-hand or automatic-direction-finder (ADF) meter, it will be seen that the pointer indicates a true bearing angle of 75 degrees. The double-scale feature of the left-hand or azimuth meter greatly facilitates the operation of checking one meter against the other since the two scales shown on the azimuth meter are reciprocals of each other, i.e., the reading of one scale is equal to 180 degrees plus the reading of the other scale. Since the true bearing from the aircraft to the ground station as shown by the automatic-direction-finder meter is the reciprocal of the azimuth angle, the reading of the automatic-direction-finder meter should agree with the reading of the nonused scale of the azimuth meter. Thus, in the case assumed for illustration, where the azimuth is assumed to be 255 degrees, the lower set of numerals on the azimuth meter represents the true azimuth scale and the upper set is disregarded. For the purpose of checking with the automatic-direction-finder meter, however, the upper or unused scale of the azimuth meter showing a figure of 75 degrees should correspond to the reading of the automatic-direction-finder meter.

At first sight, it might appear that two readings being derived from the same transmitter would be subject to the same errors so that one would not constitute a reliable check on the accuracy of the other. Practically, however, the errors of the

two readings are quite independent, so that checking one of these readings against the other is a reliable way of detecting any errors.

It is true that a complete failure, i.e., a breakdown of the transmitter or receiver, will disable both meters. This, however, will be apparent at once. The most serious danger which must be guarded against in any navigation system is not so much the danger of an obvious failure, caused by breakdown, but the danger of incorrect operation which is not apparent. It is axiomatic that no system relied on for safety of human life should be capable of giving an incorrect reading without providing some method of revealing such incorrectness.

The possible errors in the airborne direction finder of the Navaglobe system are quite independent of the possible errors in the omnidirectional-range portion of this system. The principle sources of direction-finder error are polarization errors, errors in alignment or balancing of the loop, and errors in the mechanism used for converting the loop signals into meter indications.

The principle sources of azimuth-meter error are waves reflected from large objects such as mountains in the vicinity of the transmitter, errors in relative phasing of the transmitting antennas (resulting from detuning of the antennas by sleet or sag, or from misadjustment of phase-determining circuits in the transmitter or transmission-line equipment), and finally errors in the indication equipment used for producing the pointer deflection of the azimuth meter. It can be shown that none of these errors is likely to affect similarly both the azimuth and the automatic-direction-finder meters. Therefore, by checking these meters, one against the other, the pilot or navigator can assure himself that none of these errors is present.

Although it provides two quite separate indications of each directional reading, as above described, the Navaglobe system requires only a single low-frequency receiver on the aircraft with its single loop antenna. The only equipment which is separate for the two types of readings comprises the two indicators, themselves, plus a small amount of control equipment in the receiver.

The Navaglobe airplane equipment is arranged so that fly-left and fly-right signals can be taken therefrom, for application to the right-left needle of the standard crosspointer or for application to an automatic pilot. For this purpose, the azimuth meter is provided with a colored path-selecting needle adjusted by a suitable knob; and a simple voltage divider is provided in the back of the meter for producing right-left signals in accordance

with the deviations of the airplane's azimuth from the selected azimuth as set on this colored needle.

In order that the automatic-direction-finder meter may read true bearing rather than relative bearing, the inner finely calibrated dial of this meter is arranged to be rotated by a selsyn repeater controlled from some suitable aircraft compass such as an earth-inductor, flux-gate, or gyrosyn compass. Under normal conditions, when the true north can be determined reasonably accurately, the automatic-direction-finder meter, therefore, reads true bearing and can be double checked against the reading of the nonused scale on the azimuth meter as previously described.

d. Technical Principles of Navaglobe

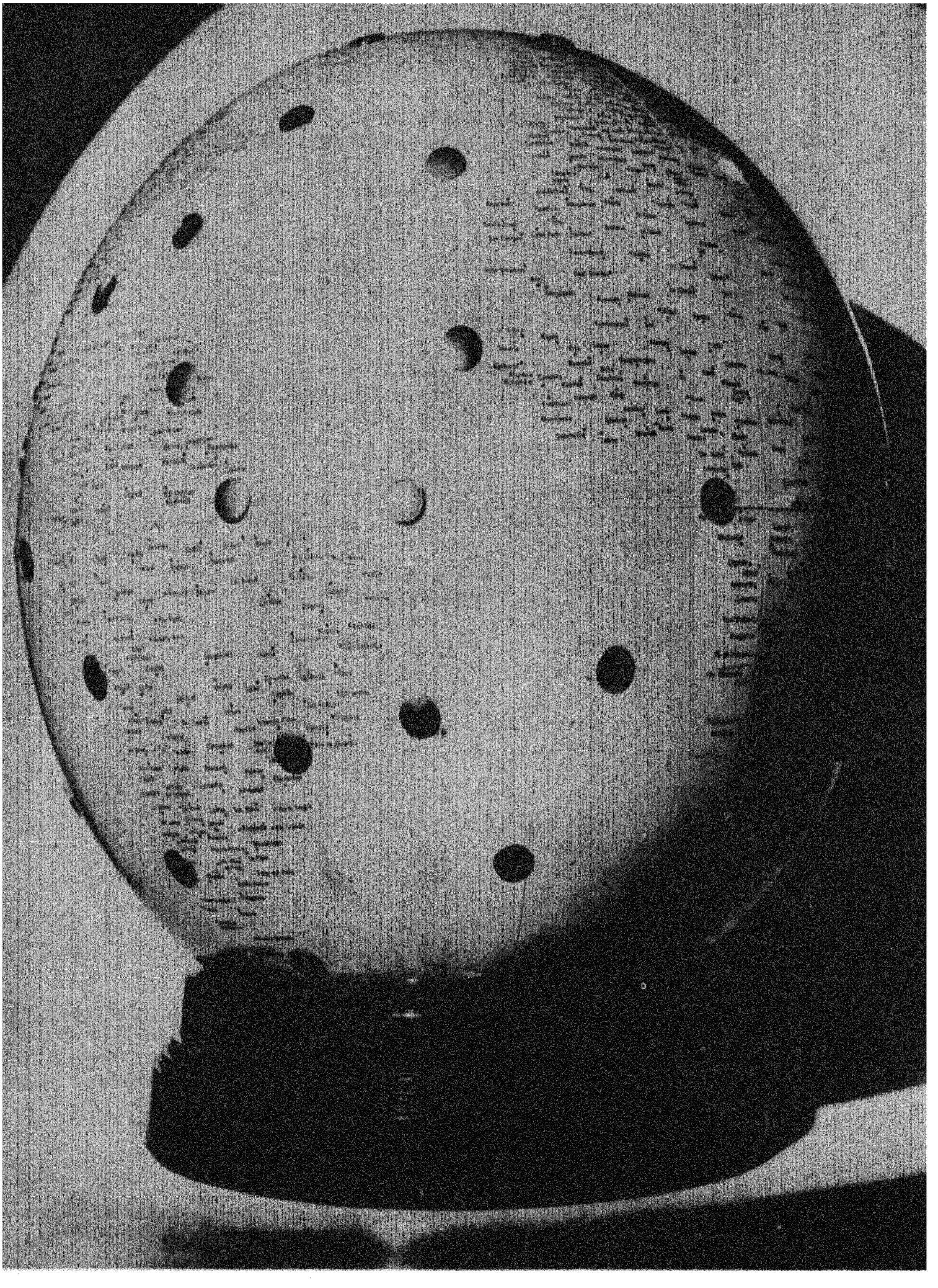
As previously mentioned, the Navaglobe principle consists basically of a narrow band long-wave omnidirectional range on the ground, with the addition of an automatic-direction-finder feature in the airborne range receiver. The omnidirectional range operates by the amplitude-comparison principle similar to the conventional 4-course ranges existing throughout the U.S.A. Instead of giving aural indications, however, Navaglobe gives direct-reading pointer-type indications. Moreover, these are given at any azimuthal position of the airplane rather than along two or four fixed courses. For this purpose, the system makes use of three successively radiated signals plus an initial synchronizing signal, the whole cycle taking place once per second.

The ground transmitter makes use of three antennas disposed in an equilateral triangle as indicated by the three dots in the center of Fig. 5. Only two of these antennas are used at any time; the A pair of antennas is used to produce the A radiation pattern, the B pair is thereafter energized to produce the B radiation pattern, and lastly the C pair is used to produce the C radiation pattern. To produce these patterns, the antenna separation is 0.4 wavelength at the operating frequency, and the excitation of the antennas is co-phasal. Three antennas, it may be remarked, are the minimum theoretical number for giving omnidirectional service.

The three successive signals are separated in a receiver and applied to a mechanism that produces the required indication by a process of vector comparison. The function performed by this mechanism is the same as would be performed by a ratiometer consisting of three coils disposed at 120 degrees and a magnetic needle which aligns itself with the resultant field. Such a needle would indicate directly the desired azimuth angle. The only ambiguity is 180 degrees, which for fixes is no ambiguity at all.

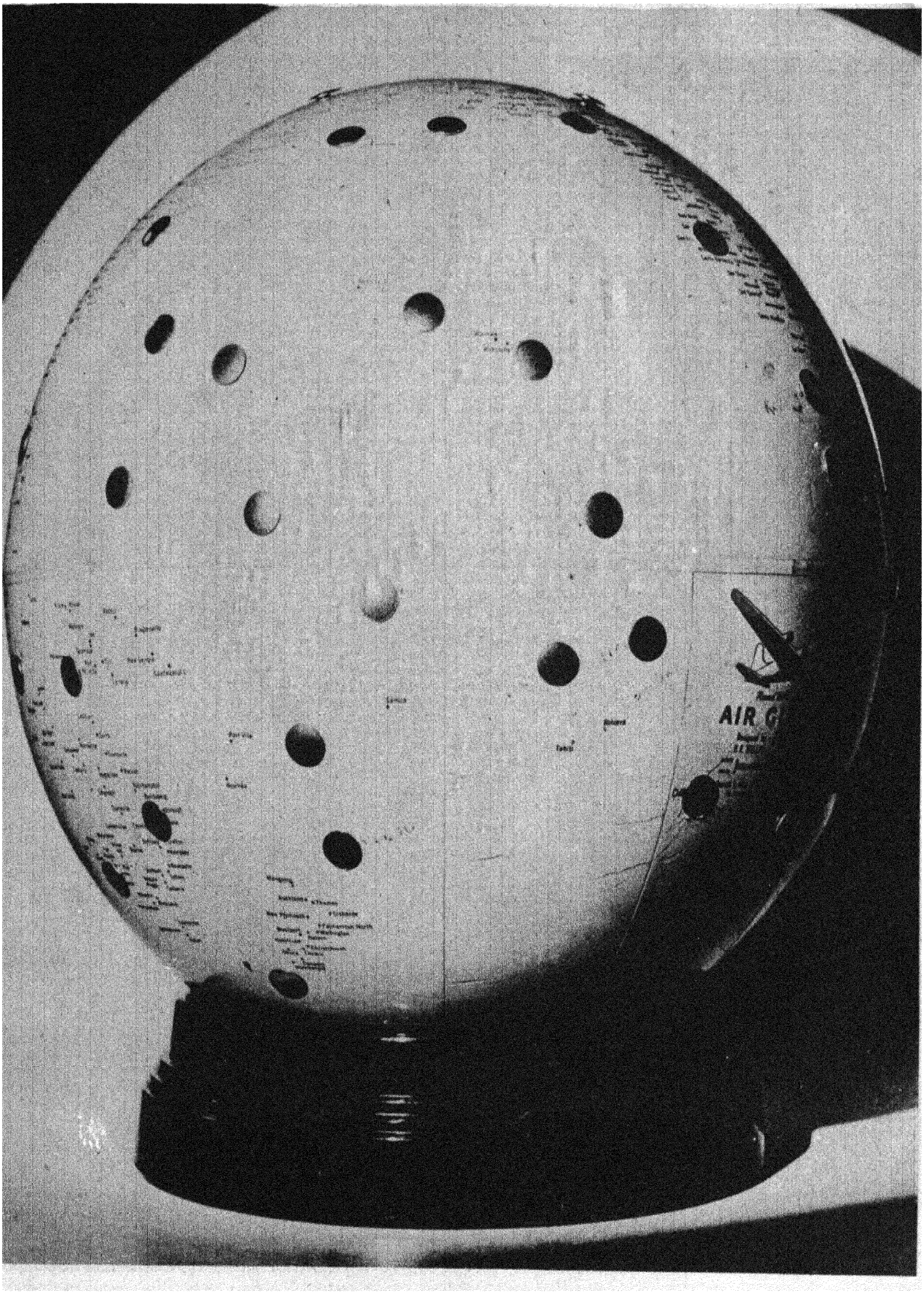
To insure reliable operation under conditions of severe noise, the receiver bandwidth is made extremely narrow, preferably of the order of 20 cycles total; and in addition, the signals may be integrated over a period of several seconds to average out the effects of noise. In such a case, the effective accuracy is equal to that which would be attained with a bandwidth of the order of 0.3 to 0.15 cycle per second. Both the azimuth and automatic-direction-finder meters consequently may be somewhat sluggish in their operation under worst atmospheric conditions and it is estimated that these meters may require approximately 10 seconds to come to rest in position for taking a reading. It is believed that this sluggishness is a very small price to pay for the exceptionally high reliability which the Navaglobe system promises to provide.

P. R. Adams and R. I. Colin
Federal Telecommunication Laboratories, Inc.



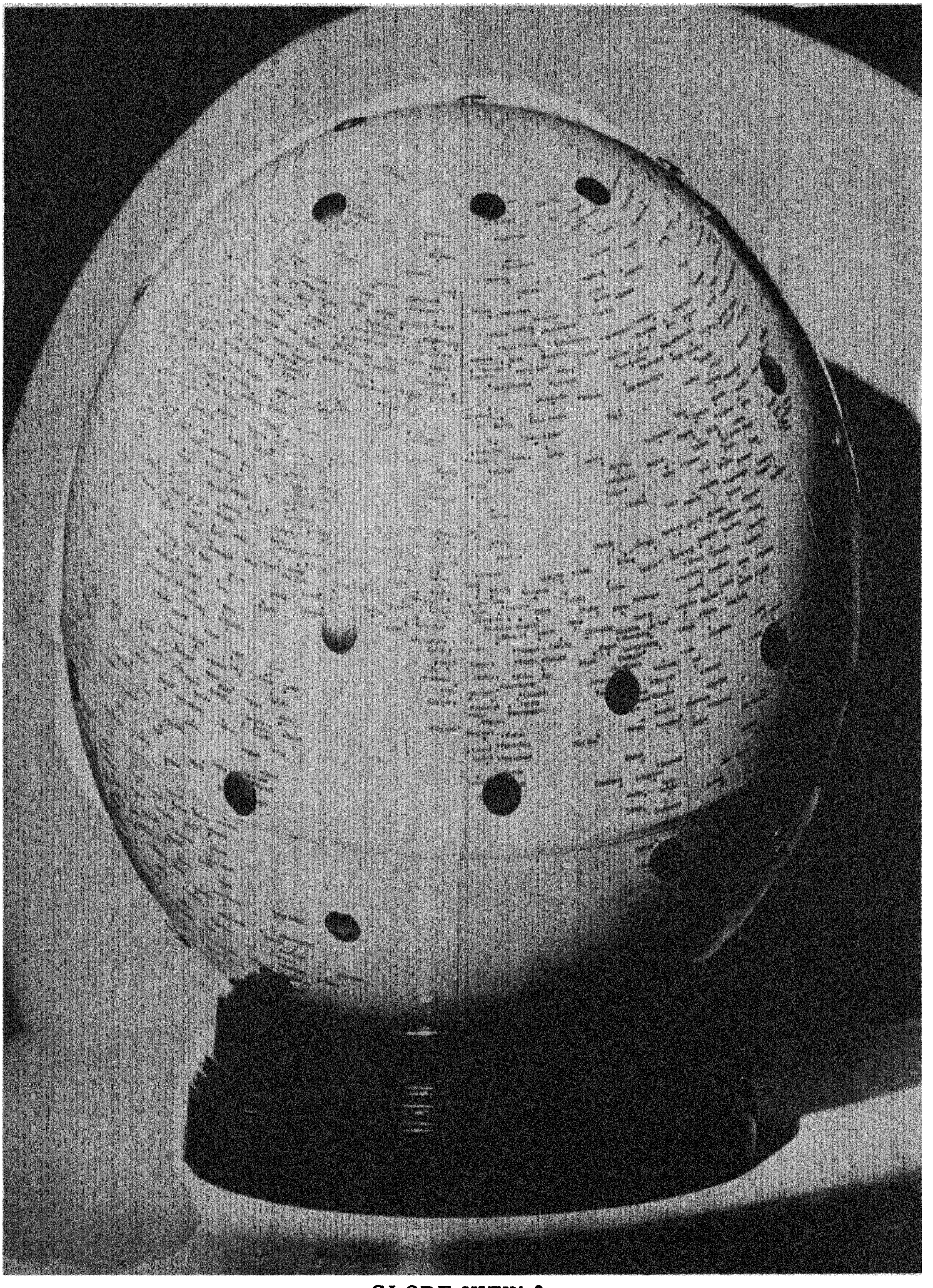
GLOBE VIEW I

Base map copyright by Rand McNally & Co., Chicago, Ill.



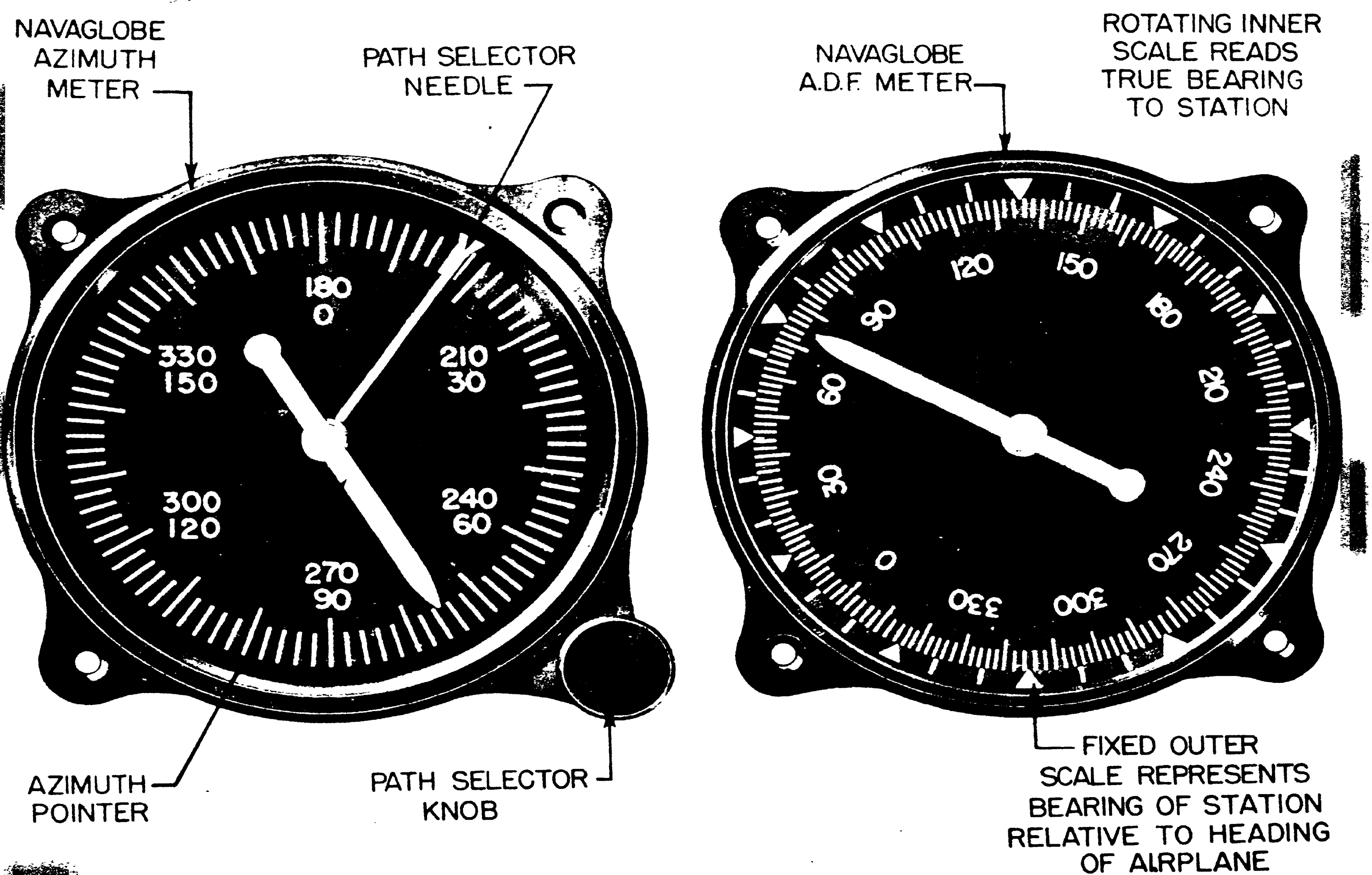
GLOBE VIEW 2

Base map copyright by Rand McNally & Co., Chicago, Ill.



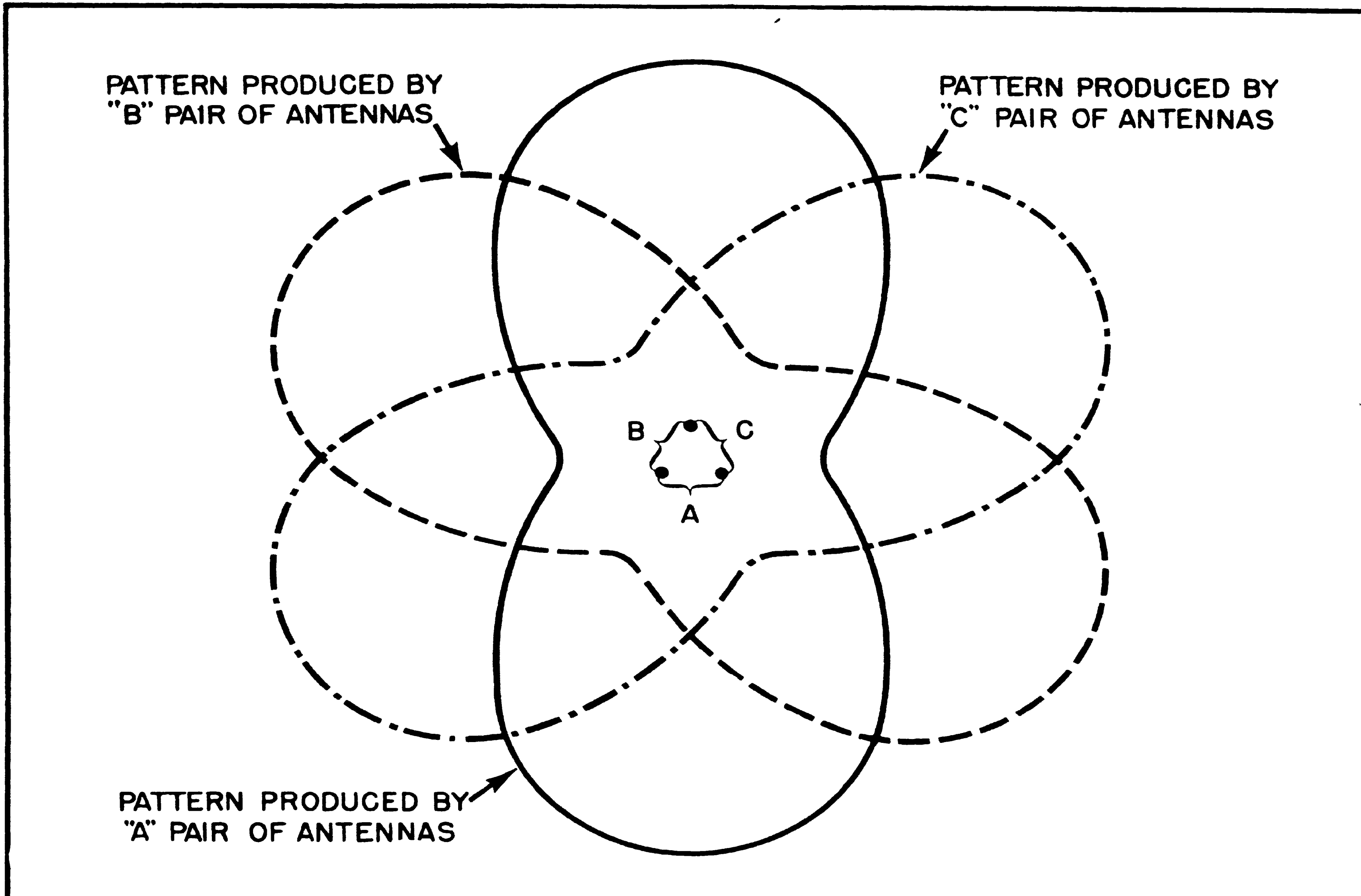
GLOBE VIEW 3

Base map copyright by Rand McNally & Co., Chicago, Ill.



APPEARANCE OF STANDARD NAVAGLOBE INDICATORS

784078 O—48——42



RADIATION PATTERNS FOR STANDARD NAVAGLOBE

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN. · · · APRIL 28-MAY 9, 1947

TELERAN - A SYSTEM OF AIR NAVIGATION AND TRAFFIC CONTROL

- By -

HUGH SPENCER
RCA - VICTOR DIVISION

ABSTRACT

This paper presents a description of TELERAN, a system of air navigation and traffic control employing television and radar as the means for collecting information and instructions required for controlled flying and displaying them pictorially in the aircraft.

While not recommended as a marine navigational aid, it has been thought that a description of the system would be of sufficient general interest to warrant its inclusion in the list of subjects to be covered in these meetings. Diagrams indicating the various types of display which may be presented to pilots by this system are appended.

TELERAN - A SYSTEM OF AIR NAVIGATION AND TRAFFIC CONTROL

1. While the principal focus of attention of the International Meeting on Marine Aids to Navigation is on aids to navigation of water-borne traffic, it is probably worthwhile to spend a little time in the deliberations to discuss a system of navigation and traffic control which is under development for the field of air transport. This is desirable not because the system to be described fits the requirements for the navigation of surface vessels but to point out the differences in limitations and requirements between aerial and water-borne traffic and to point out the differences in system design which these requirements and limitations impose.

2. Teleran is not recommended as a navigation aid for surface vessels. For long-distance navigation, Loran remains the appropriate agency to aid the master of a vessel in establishing his course. Indeed, in the field of aircraft it is probable that Loran will be the appropriate navigational aid for long-distance over-water flights. For short-range navigation - after a landfall has been made - ship-borne radar is an effective tool. The ability of ocean-going craft to carry apparatus of heavy weight makes high-definition ship-borne radar extremely attractive. This capability does not, of course, exist in aircraft. A ship on approaching its port can, in case of foul weather conditions, stand on and off, or in the case of engine trouble, come to anchor. While circling outside the airport is perhaps the aerial equivalent of standing on and off, no one has yet discovered an appropriate technique for bringing an aircraft to anchor. The inherent requirement of aircraft to maintain way and the extreme premium imposed by economy on lightness of weight are the two characteristics which stimulate navigators to look beyond airborne radar in the solution of the problem of air navigation and traffic control.

3. Teleran derives its name from the comgination of television and radar for air navigation. The system is under development by Radio Corporation of America under sponsorship of the Air Materiel Command of the United States Army Air Forces and with the close cooperation of the United States Civil Aeronautics Administration.

Figure 1: "Functional Diagram of the Basic Teleran System"

4. Ground-sited radar scans the sky and receives signals from all the aircraft within its range of coverage. Thus the ground Teleran installation has continuous knowledge of the point on the ground over which each aircraft within the range of coverage is flying.

5. The three-dimensional character of an aircraft's course, however, imposes the requirement of further information if safe and expeditious navigation in foul weather is to be achieved. Therefore, installed on each aircraft is a transponder or beacon which when swept by the ground radar responds in a series of pulses. The time spacing between the pulses is determined by the altitude at which the airplane is flying. Thus through the interconnection of the transponder and the aircraft and the aircraft's al-

timeter, the ground installation has available continuously the location of each aircraft, in plan projection. By means of the coded signal its altitude is known.

6. A convenient method of utilizing the information as to altitude is to incorporate in the radar receiver a decoding circuit or sieve which sorts out the received signal in accordance to altitude layers. These signals are then displayed on separate radar presentation tubes. Thus the first tube might present the location of all aircraft flying at 2,000 feet or less, the second tube those from 2,000 to 4,000 feet and so on. Figure 1 shows three radar presentation tubes corresponding to three altitude layers. The equipment is planned to present at least eight such layers.

7. A television camera scans each radar presentation tube and the pictures produced in it are broadcast aloft to television receivers located in the aircraft. Thus each television-equipped plane can receive pictures showing the location of every aircraft in his vicinity and the altitude layers within which they are flying.

8. Such information is helpful and perhaps adequate as a means of preventing collisions. For navigation, however, it is necessary that the location of the aircraft be corollated with the terrain over which the flight takes place. Therefore, transponder charts on which are drawn the important features of the ground terrain are placed between the radar display tube and the television camera so that the television picture produced consists of a map of the terrain surrounding the tower and station with pertinent features shown and with the aircraft in the vicinity superposed upon it. Thus each airplane receives a picture showing the area 100 miles in diameter - for en route navigation between airports - with the airways marked on it, the location of airports, key information as to the frequencies of the Teleran facilities within the area, and the location of all the aircraft in its vicinity.

9. In order to avoid any possible ambiguity as to which of the spots on the screen representing the several aircraft is his own, a bright line automatically drawn from the center of the display to its outside edge passes through the radar pip corresponding to the airplane on which the picture is received.

Figure 2: "Typical En Route Chart Received by an Aircraft Flying in the 10,000 to 15,000 Feet Layer."

10. Figure 2 shows the type of picture which might be received by an airplane flying at 12,000 feet southwesterly along airway 12-134. It is worth emphasis that the spots of light representing the aircraft are not circular in form but are tear-dropped in shape so that the orientation of the teardrop on the television screen gives an indication of the track of the aircraft along the airway. It is a convenient characteristic of the television pickup tube that the signal produced by the radar display is stored on the target of the television tube so that one bright flash in the radar tube representing the position of an aircraft is repeatedly scanned and transmitted aloft until the next flash occurs on the successive rotation of the radar antenna. Thus the radar signals for succes-

sive scanning cycles merge together and produce an image on the television screen which is brighter and larger at its leading edge, dimmer and smaller at the rear. The pilot now has a clear indication of his position and the position of the aircraft surrounding him. In addition, since leeway is a more important factor in airplanes than in the steering of most ships, it is necessary for him to know his heading so that the course can be continuously made good. This is accomplished by mounting a disc in front of the television display tube with ruled lines parallel on it. This disc is connected with the gyro compass in the aircraft so that it shows at a glance the true heading of the aircraft. Thus the aircraft shown on Figure 2 is maintaining a heading of approximately 138° in order to make good a course of 134°. This is required by the 20-mile wind indicated near the top of the picture as blowing toward bearing 24°. The character of the maps presented on the various altitude layers would probably be different. Figure 2 for 10,000 to 15,000 feet shows a minimum of ground features, the location of two airports - Wilkes-Barre, indicated by the conventional signal WI, and Allentown, indicated by XA - being all that is required. The lower altitudes, however, are presented in greater detail.

<u>Figure 3: "Typical Television Chart for 2,000 to 4,000 Foot Layer"</u>

11. Figure 3, a typical chart for the same vicinity as Figure 2 but at the 2,000 to 4,000 foot level, shows in addition to the two major airports, Wilkes-Barre and Allentown, five other auxiliary airports. In addition, hills are shown, one near the upper left edge of the picture of 2,000 feet, another similar 2,000-foot hill near the top. In addition, since aircraft flying at this elevation are presumably interested in making a landing or in departing from an airport, the paths are shown whereby the pilots may leave the main airways and enter the airport approach zone.

12. In the airport approach zone even greater detail is required than is necessary for en route navigation at the lower levels. Therefore a separate radar located at the airport and having a range of some twenty miles is used. Figure 3 shows an airplane flying easterly along airway 6. Immediately in front of this airplane is a small circle dotted on the chart which indicates the area covered by the airport approach zone and indicates that the Teleran station associated with that airport in No. 4. Were the pilot of this aircraft interested in landing at this airport, he would, as he reached the edge of the circle, turn his station selector to No. 4 and would thereupon receive a picture similar to that shown in Figure 4.

<u>Figure 4: "A Typical Airport Approach Zone"</u>

13. This map, forty miles in diameter, shows the topographical obstructions in the vicinity of the airport, the long ridge 1,000 feet high northwest of the airport, two small hills approximately 1,000 feet each southeasterly of the airport, and the airport itself at an altitude of 380 feet. In addition the name of the airport, XA for Allentown, together with the conventional symbols for the weather conditions obtaining and the barometric

correction at that particular time are displayed.

14. The traffic pattern by which aircraft approach and leave the airport are shown on charts of this type. Such patterns are not rigid but are a changing function of the wind force, its heading, the runway to be used, and the density of traffic. Figure 4 shows the condition for an east wind of eight miles per hour.

15. It is a part of the traffic control philosophy which derives from the Teleran system that the airways are removed from the airports just as in land traffic planning the main trunk highways are removed from the towns and smaller cities. This permits a possibility of arranging a smooth flow of traffic in and out of the airport with only one possible point of conflict - the point at which the final approach for landing is made. This is shown on the chart of Figure 4 at 2,000 feet with the instruction "start Descent".

16. The entire system for combining drawn charts with radar information is extremely flexible so that under changing conditions the charts are readily changed. All that is necessary is for the ground traffic controller to draw or write on the chart special instructions to any aircraft under his control. Thus Figure 4 shows that the aircraft approaching from airway 7-056 has received instructions to hold, presumably so as to give clearance to the aircraft receiving this picture - identified by the radar line passing through it - to make his landing first.

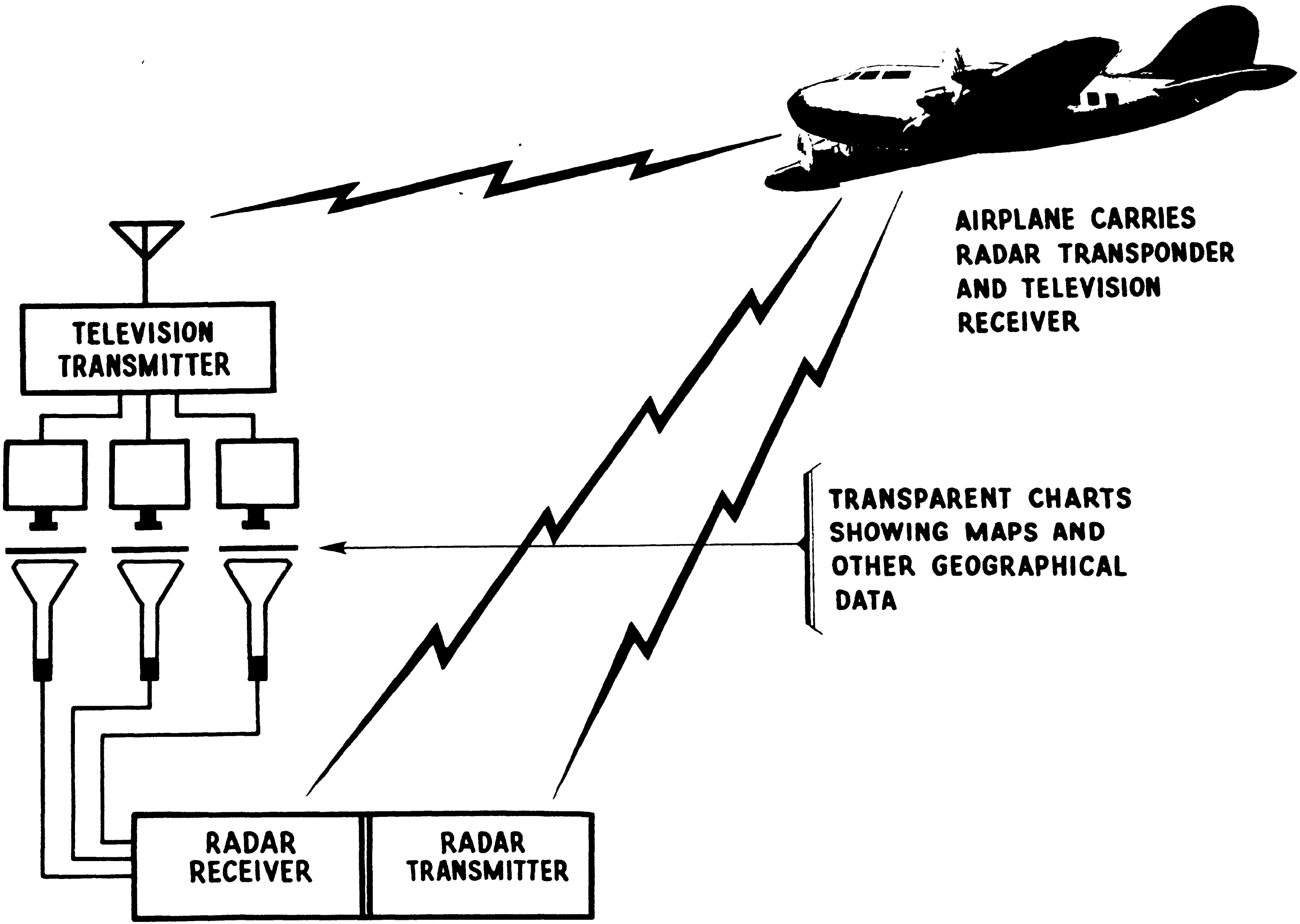
Figure 5: "Teleran Landing Display"

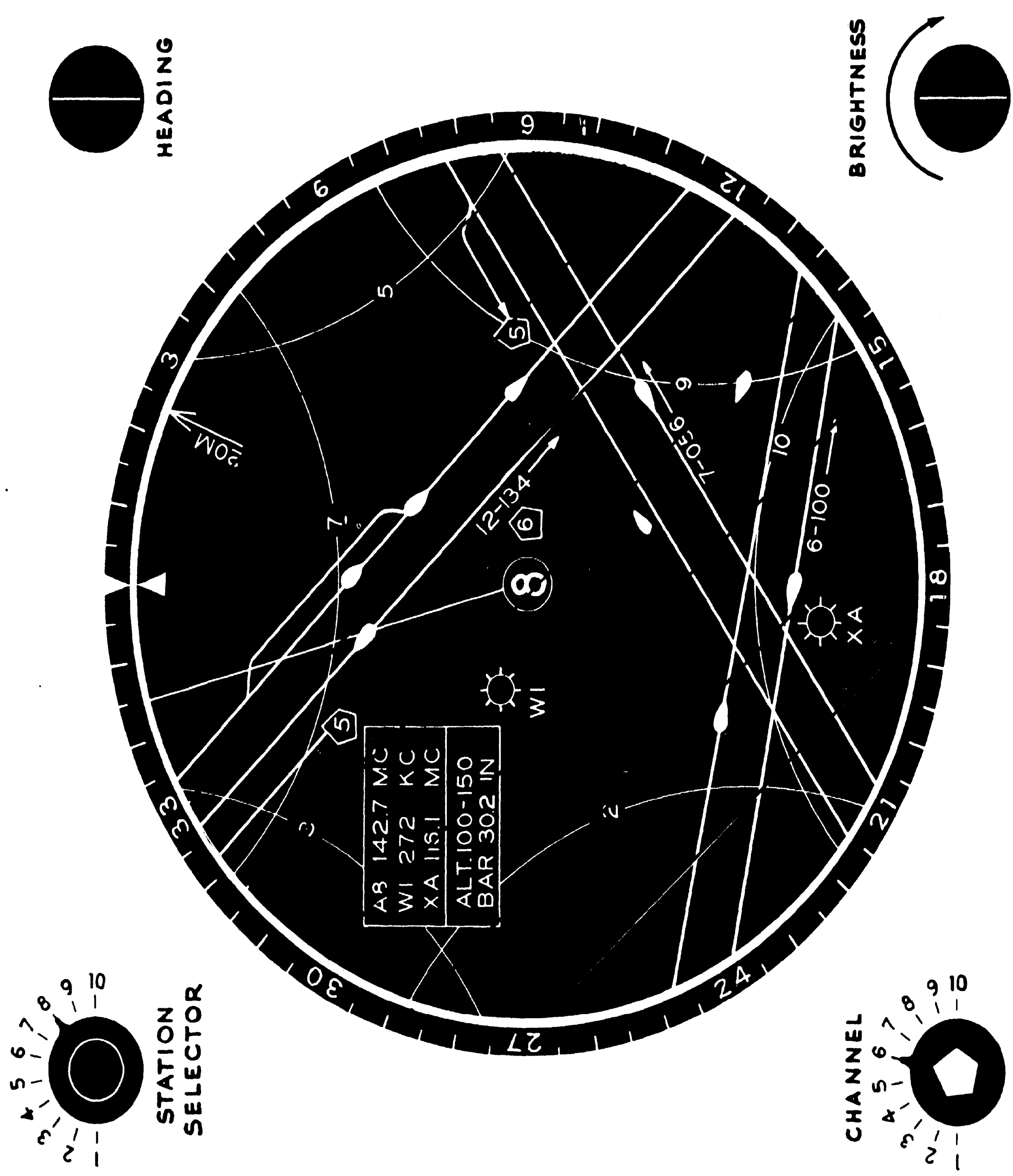
17. As the aircraft passes the final approach point, the pilot turns his receiver so as to obtain a special type of display appropriate for landing. Such a display is shown in Figure 5. It is basically different from each of the other charts so far mentioned. In every other case geographically-north is shown at the top of the television display tube so that the map presented to the pilot is displayed erect in the manner in which it is most natural to read maps and charts. On the landing display, however, the airport is always shown at the top of the television picture with the runway to be used lying on the vertical diameter of the display tube. The center line of the runway extends as a bright vertical line across the face of the tube for approximately eight miles - the length of the glide path and the precision GCA radar. The radar signals for this display are in fact obtained from the GCA radar, slightly modified. The left-right scan located the aircraft, so that the plane just having entered the landing zone sees himself as a bright spot near the bottom of the display. Figure 5 shows the plane somewaht to the left of his true path as indicated by the vertical line extending from the runway. In addition, a horizontal line is automatically drawn across the vertical line to indicate the vertical position of the airplane in respect to the glide path. If the airplane is too high it is shown above the horizontal line. If it is too low, it appears below it. Thus an aircraft shown near the bottom of Figure 5 is not only to the right but too low so that the rate of the descent should be reduced in addition to the direction changed to bring

him onto the true approach path. The airplane at the top of the picture is exactly on course at the intersection of the horizontal and vertical lines. As the plane proceeds along the approach path the horizontal line progresses with it up the face of the television tube so that it is necessary for the pilot simply to maintain his display position at the intersection of the two lines. Wind directions are indicated at the surface and at various altitudes along the approach path so that the pilot is able to plan for his approach course with full knowledge of the movement of the air mass through which he plans to fly.

18. If the method for producing the pictures for various altitudes were to assign to each altitude layer a television transmitting signal, the system would require a rather large portion of the frequency spectrum. Fortunately, this is not necessary. A time multiplex system whereby frames of the television picture in rotation pick up different altitude layers is used. Thus the first frame could report the altitude layer from zero to 2,000 feet, the second frame from 2,000 to 4,000 feet, and so on. Thus we have by a system of time-sharing several channels within a single basic frequency channel. It is planned that probably two of the channels thus produced will be used to transmit weather information. This will enable the pilot to get more complete weather information by receiving maps without burdening the voice communication channels already seriously loaded in the dispatching of traffic.

19. This, in summary, is the Teleran system of air navigation and traffic control. It is considered as a future system and was so classified at the Montreal meeting of the PICAO. The program is, however, proceeding smoothly. A simulated Teleran display has been installed in a Link trainer at the laboratories of RCA in Camden. During the fall of 1947 flight tests are scheduled with an airway Teleran station, an airport conveyance station, and a landing system in the vicinity of Washington, D. C. A television display tube has been developed of sufficient intensity to permit the reception of pictures in full daylight, such as might be experienced in the cockpit of an aircraft flying above the overcast. Other work unquestionably remains to be done. Specifically, the Teleran system with the azimuthal radar scan and the transponder response lends itself quite naturally to techniques of automatic flight and automatic landing. Figure 6 is a tabulation of the functions performed by the Teleran system. It indicates the appreciable saving in airborne weight which can be accomplished by the use of this system.


AIRPLANE CARRIES
RADAR TRANSPONDER
AND TELEVISION
RECEIVER
TRANSPARENT CHARTS
SHOWING MAPS AND
OTHER GEOGRAPHICAL
DATA
TELEVISION
TRANSMITTER
RADAR
RECEIVER
RADAR
TRANSMITTER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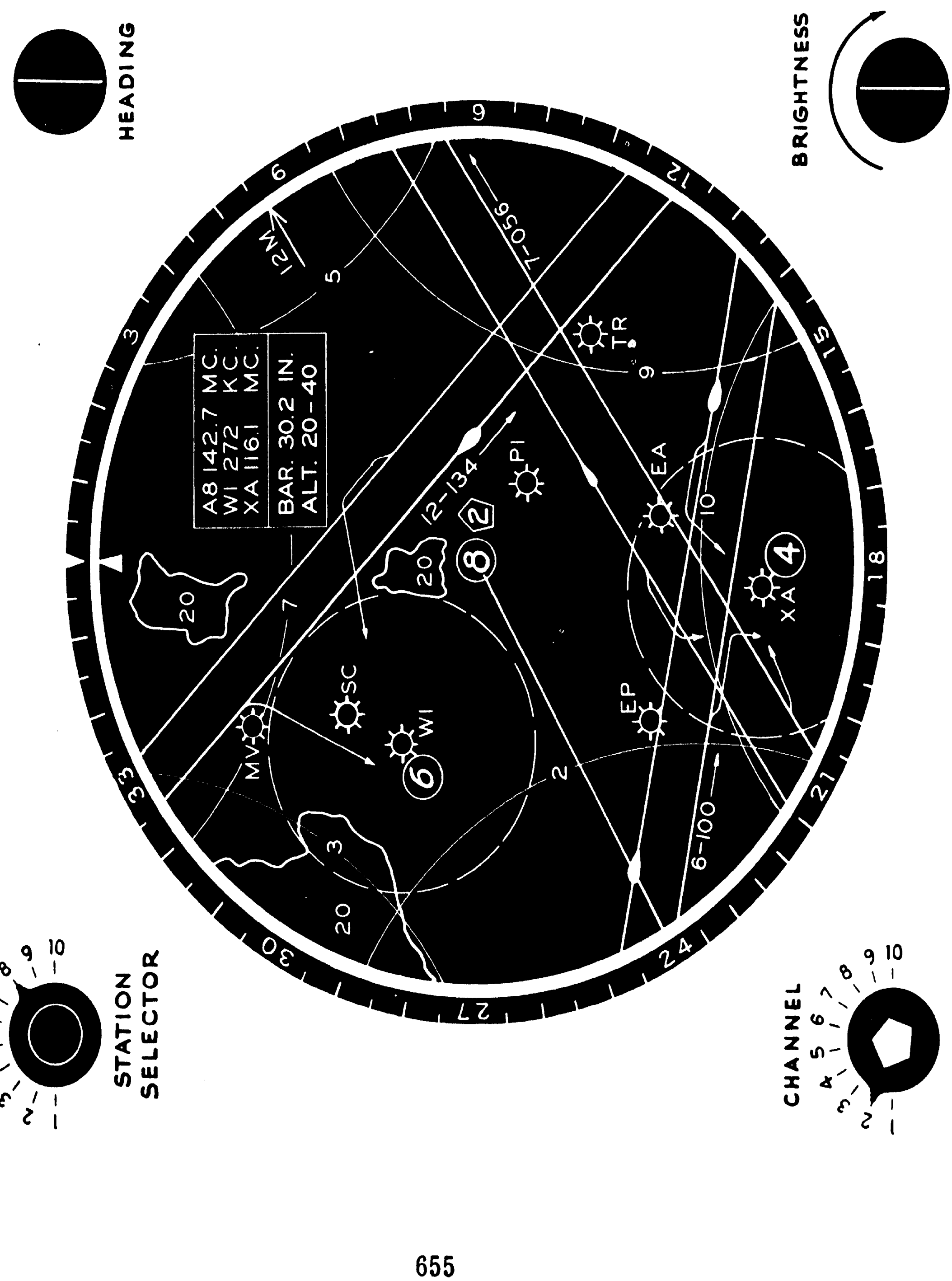
WI 272 KC
XA 115.1 MC
ALT.100-150
BAR 30.2 IN
WI
XA
12-134
7-056
6-100
20M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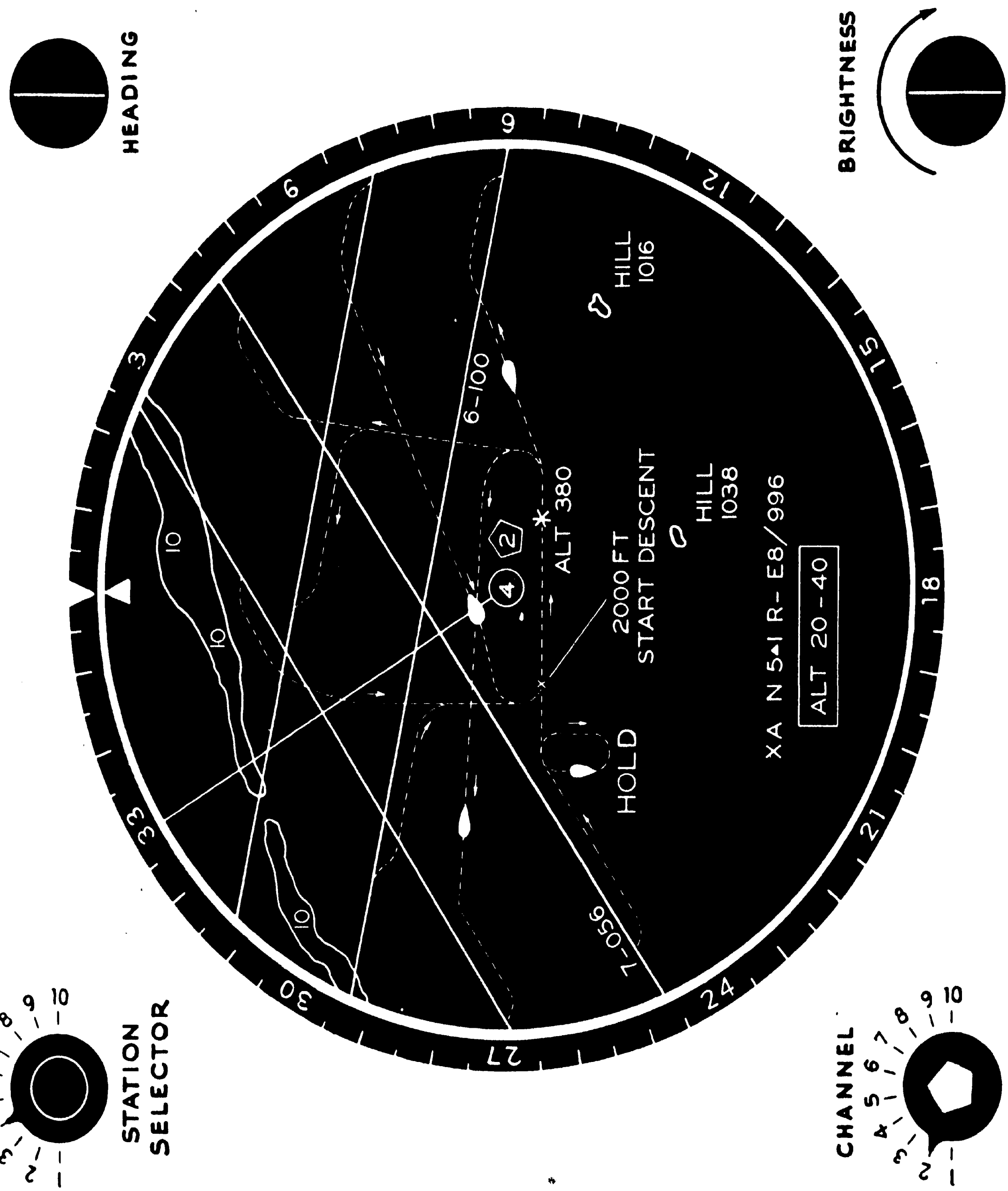
BAR. 30.2 IN.
ALT. 20-40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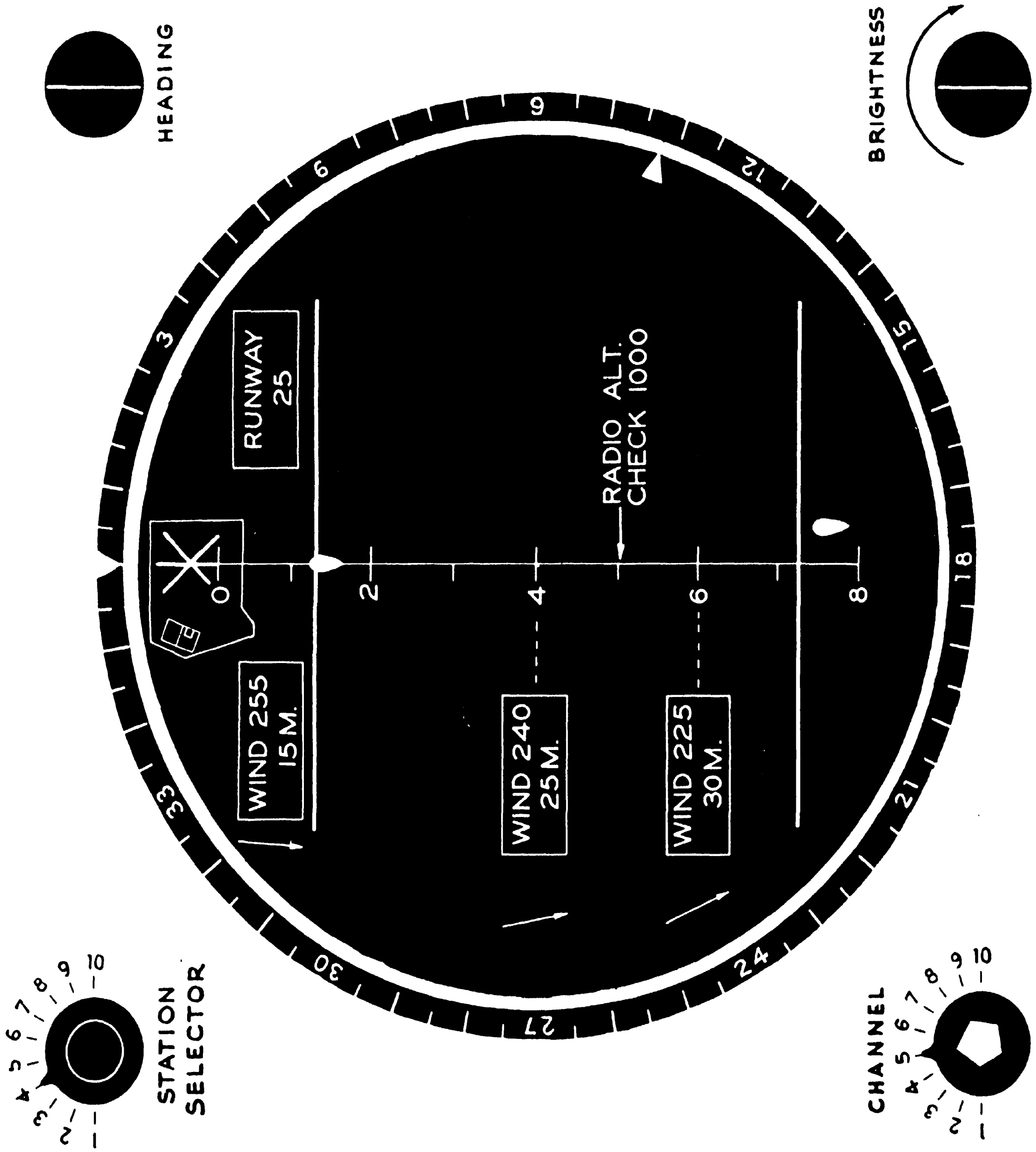
XA N 5-1 R- E8/996
ALT 20-40
7-056


HEADING
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WIND 240 25 M.
WIND 225 30 M.
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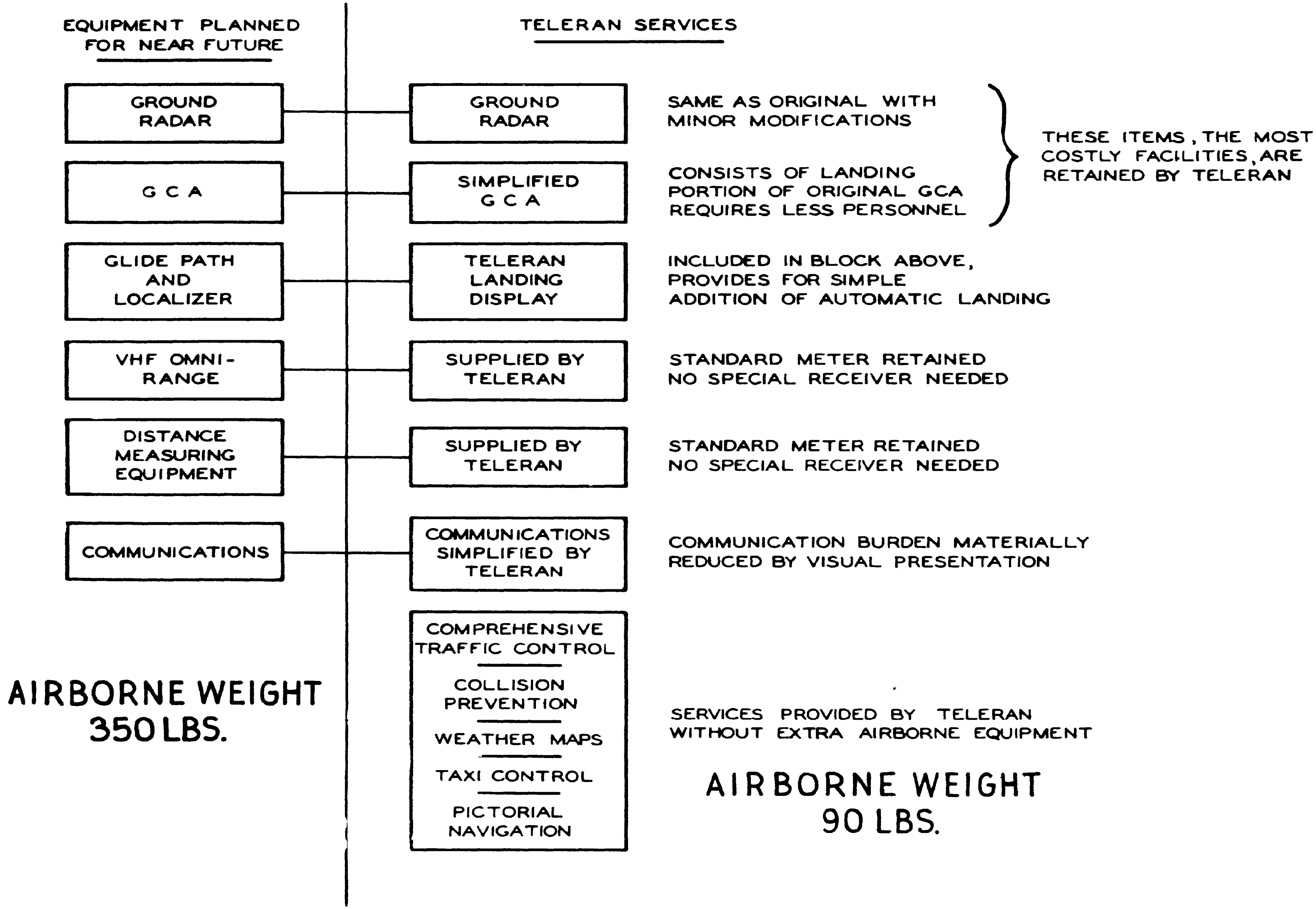

EQUIPMENT PLANNED FOR NEAR FUTURE
TELERAN SERVICES
GROUND RADAR
GROUND RADAR
SAME AS ORIGINAL WITH MINOR MODIFICATIONS
G C A
SIMPLIFIED G C A
CONSISTS OF LANDING PORTION OF ORIGINAL GCA REQUIRES LESS PERSONNEL
THESE ITEMS, THE MOST COSTLY FACILITIES, ARE RETAINED BY TELERAN
GLIDE PATH AND LOCALIZER
TELERAN LANDING DISPLAY
INCLUDED IN BLOCK ABOVE, PROVIDES FOR SIMPLE ADDITION OF AUTOMATIC LANDING
VHF OMNI-RANGE
SUPPLIED BY TELERAN
STANDARD METER RETAINED NO SPECIAL RECEIVER NEEDED
DISTANCE MEASURING EQUIPMENT
SUPPLIED BY TELERAN
STANDARD METER RETAINED NO SPECIAL RECEIVER NEEDED
COMMUNICATIONS
COMMUNICATIONS SIMPLIFIED BY TELERAN
COMMUNICATION BURDEN MATERIALLY REDUCED BY VISUAL PRESENTATION
COMPREHENSIVE TRAFFIC CONTROL
COLLISION PREVENTION
WEATHER MAPS
TAXI CONTROL
PICTORIAL NAVIGATION
SERVICES PROVIDED BY TELERAN WITHOUT EXTRA AIRBORNE EQUIPMENT
AIRBORNE WEIGHT 350 LBS.
AIRBORNE WEIGHT 90 LBS.

INTERNATIONAL MEETING ON MARINE RADIO AIDS TO NAVIGATION
NEW YORK CITY AND NEW LONDON, CONN · · · APRIL 28-MAY 9, 1947

LORAN—STATISTICAL DATA SUBMITTED BY THE UNITED STATES DELEGATION

1. The present Loran System coverage of the world includes a large part of the main arteries of Marine and Air Commerce. Figure 1 shows the specific coverages now available. Of the 37 Loran transmitting stations now in operation, 13 are in the Atlantic and 24 are in the Pacific Ocean areas. Their operation is an international cooperative program in that Canada, Denmark, Iceland, United Kingdom, and the United States are jointly maintaining stations. While it is sometimes considered that Loran stations are in groups of three, that is, one double master and two slave stations, it is noted that this system is well adapted to providing continuous coverage over long areas with a rather economical number of stations; for example, the 13 stations in the Atlantic provide 10 lines of position over an area extending from the northern Caribbean Sea to the British Isles, some 4800 nautical miles airline around this circuit, with charted fix areas being shown over all but a small part both day and night. Actually, navigators report that continuous ground wave coverage (daytime as well as night) is being consistently obtained over the whole of the route.

2. This extensive system, in addition to being the most accurate long range system in use or operationally tried to date, has, because it is a pulsed system, many other advantages not enjoyed to the same degree by other long range aids, such as ability to operate through interference, normal static, and precipitation static long after CW systems are unusable. Furthermore, the economic investment is not small and must be considered as an important factor in its retention, adoption, and expansion.

It is desirable to note that the present worldwide system was installed during World War II with the bases then available and that peacetime expansions can reasonably be expected to be considerably more efficient with regard to overall coverage, fix areas, economy of stations, accessibility, etc., than some of the present stations.

3. The following table lists the order of observed accuracies of Loran lines of position (the geometrical accuracy is considerably higher):

Synchronization accuracy with normal baseline is 1 microsecond.

Along the baseline between paired transmitting stations, accuracy is 1000 feet (1 microsecond is 500').

	Distance from Midpoint of Baseline		
	500 N.M.	1000 N.M.	1400 N.M.*
Baseline 200 N.M. Centerline	2.0 N.M.	4.0 N.M.	5.4 N.M.
Baseline 250 N.M. Centerline	1.5	3.8	5.0
Baseline 300 N.M. Centerline	1.4	3.7	4.8
Baseline 350 N.M. Centerline	1.3	3.6	4.6

* Expressed in degrees an error of 5 N.M. is about 0.3° at 1400 N.M.

The existing station baseline lengths are as follows:

76% between 200 and 350 N.M.

16% between 350 and 700 N.M.

8% between 100 and 200 N.M.

Loran position line accuracy over the coverage area is dependent upon the geometry of the lattice, the same as for any hyperbolic system.

LORAN INSTALLATIONS
IN OPERATION APRIL 15, 1947

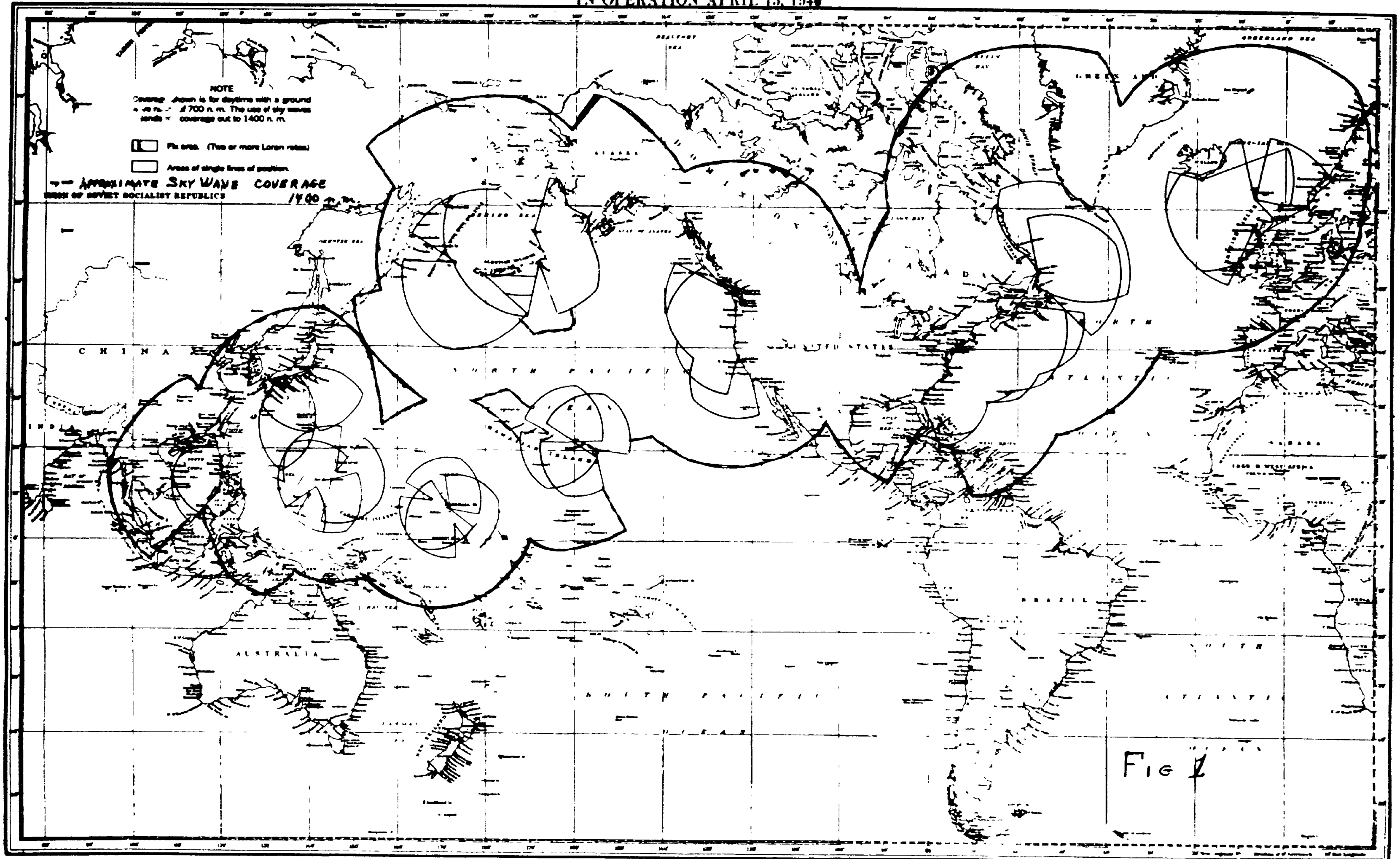

Fig 1

SHIPBORNE DIRECTION FINDERS AND
ASSOCIATED RADIOBEACONS

Submitted by the
United States Delegation

The early availability of the medium frequency direction finder and the worldwide setup of simple radiobeacons resulted in the situation that, for many years, allowed no basic change of technique in the marine radio direction finding field. Progress resulted only from refinements, better design, and acquired experience.

There are definite indications that improvements can be introduced with respect to the presentation of the information to the user, automatic indication of bearings, or automatic position fixing. Provided an adequate developmental effort is applied, there are strong indications that marine DF could be combined with distance measuring equipments to result in an attractive position fixing scheme from one source. There are indications that the present limitation of accurate range at night could be improved and the range increased by using different types of transmissions; this would require development and eventually changes or additions to the present marine radiobeacons which would make the improved service available to new direction finders, with the old and new systems being capable of simultaneous operation in the interim period.

Annex A

LIST OF DELEGATES, ADVISERS, AND SECRETARIAT

ARGENTINA

Delegates	Captain Rogelio R. Alcantara, Argentine Navy
	Rear Admiral Harold Cappus, Argentine Navy
	Captain Alfonso Rene Malagamba, Argentine Navy

AUSTRALIA

Chairman	R. V. McKay, Chief Engineer, Department of the Postmaster General
Delegates	W. R. Baird, Engineer, Overseas Telecommunications Commission
	J. L. Mulholland, Assistant General Manager, Overseas Telecommunications Commission
	E. S. Stewart, Assisting Supervising Engineer, Department of the Postmaster General
Observers	Andrew Crome, Australian General Electric Pty., Limited, Sydney, Australia
	Alan Whitfield, Australian General Electric Company, Sydney, Australia

BELGIUM

Observer	Gerard de Burlet

BRAZIL

<u>Delegates</u>

Lieutenant Commander Jose Paulo De Albuquerque Guillobel,
Brazilian Navy

Lieutenant Commander Waldeck Lisboa Vampre,
Brazilian Navy

CANADA

<u>Chairman</u>

A. N. Fraser,
Senior Radio Engineer, Department of Transport

<u>Delegates</u>

Commander H. G. Burchell,
Royal Canadian Navy, Assistant Director of Electrical Engineering

D. I. Cameron

Gordon K. Davidson,
Engineer, Marine Section, Ontario Hughes-Owens Company, Limited

W. J. Gray,
Assistant General Manager, Canadian Marconi, Limited

W. L. Haney,
Assistant Research Engineer, National Research Council

Lieutenant Commander W. D. F. Johnston,
Royal Canadian Navy, Staff Navigation Officer, Naval Services Headquarters

Captain J. W. Kerr,
Supervisor of Nautical Services, Department of Transport

I. W. W. Martin,
Canadian Arsenals, Limited

James H. Rowlatt,
British Canadian Electronic Instruments, Limited

CANADA (continued)

W. E. White,
Electrical Radar Engineer, Canadian Arsenals, Limited

CHILE

Delegate — Lieutenant Commander Alberto Andrade,
Naval Attache, Embassy of Chile,
Washington, D. C.

CHINA

Chairman — W. H. T. Wei,
Assistant Manager, China Merchant Steam Navigation Company

Delegates — Henry B. Lee

T. S. Wang

Secretary — T. K. Yu

Observers — J. J. Lee

C. Shio

COLOMBIA

Delegate — Lieutenant Jorge E. Palacio,
Embassy of Colombia,
Washington, D. C.

DENMARK

Delegates — Captain J. Hauptmann-Andersen, D.R.N.,
Superintendent, Testing Establishment Nautical Instruments

Aksel Skov Knudsen,
Head, Technical Section, Danish Lighthouse Service

Arnold Poulsen,
Consulting Engineer to the Ministry of Commerce and Shipping

Observer — C. Lief Christensen,
Engineer, Danish Chamber of Commerce, Shipping, D.P.F.

ECUADOR

Delegate	Captain Francisco Fernandez Madrid, Naval Attache, Embassy of Ecuador, Washington, D. C.

FINLAND

Delegates	Ville Niskanen, Consul General in New York
	Professor Viljo V. Ylostalo

FRANCE

Delegates	P. B. F. David, Chief Engineer of Naval Constructions and Chief of Marine Section of Central National Studies of Telecommunications
	M. Loranchet, Deputy Director of Economic Affairs and Naval Material in General Secretariat of Merchant Marine Ministry
	P. Petry, Assistant Director, Service of Lighthouses and Beacons of the Ministry of Public Works and Transports

GREECE

Delegate	Lieutenant Georges Soubassakos, Royal Greek Navy

INDIA

Delegate	A. N. Seal, Engineer-in-Chief, Lighthouse Department

IRAN

Delegate	Commander Mohammad Ardalan, Assistant Military Attache, Embassy of Iran, Washington, D. C.

ITALY

<u>Delegates</u>

Professor Torquato Carlo Giannini,
Counsel, Italian Merchant Marine Ministry

General Carlo Matteini,
Italian Merchant Marine Ministry

Captain Vincenzo Vaccarisi,
Italian Navy, Head, Telecommunications Office

MEXICO

<u>Delegates</u>

Lieutenant Commander Jose A. Cerdan Munoz,
Mexican Navy

Lieutenant Jose Ferron Romo,
Mexican Navy

Lieutenant Commander Alberto Marin Luviano,
Mexican Navy

Lieutenant Higinio Perez Segrove,
Mexican Navy

NETHERLANDS

<u>Chairman</u>

A. J. W. van Anrooy,
Chief, Marine Radio Communications; Member, Radar Committee and Vice Chairman of Netherlands Delegation, World Telecommunications Conference

<u>Delegates</u>

W. A. F. Liebert,
Member, Radar Committee and Delegate, World Telecommunications Conference

Rear Admiral J. E. M. Ranneft,
Royal Netherlands Navy, Naval Attache, Embassy of the Netherlands,
Washington, D. C.

Professor R. Roelofs

J. T. Verstelle,
Member, Netherlands Navy Hydrographic Bureau

NEW ZEALAND

<u>Delegates</u>

T. R. Clarkson,
Divisional Radio Engineer

H. W. Curtis,
Divisional Director of Telecommunications

NORWAY

<u>Delegates</u>

Olaf Moe,
Delegate to World Telecommunications Conference

Captain Kristian Ostby,
R.N.N., Naval and Air Attache, Embassy of Norway, Washington, D. C.

<u>Observer</u>

H. B. Andresen,
Norwegian Shipowners Association

POLAND

<u>Delegates</u>

Janusz Groszkowski,
Director, Polish Radio Technical Institute

Antoni Zielinski,
Gdynia American Line

PORTUGAL

<u>Delegates</u>

Lieutenant Commander Jorge Maia Ramos Pereira,
Director of Electricity and Communications Services of Ministry Marine; Member Portuguese Delegation, World Telecommunications Conference

Lieutenant Antonio Bernardino Ferreira Monteiro,
also Member, Portuguese Delegation World Telecommunications Conference

SIAM

<u>Delegates</u>

Captain M. C. K. Abhakorn,
Naval Attache for Air, Embassy of Siam, Washington, D. C.

SIAM (continued)

Luang Praisanee,
Assistant Director General of Boats and Telegraphs

SWEDEN

<u>Chairman</u> Commander Sven F. Forsberg,
Royal Swedish Navy

<u>Delegates</u> Lieutenant Commander Axel Os Bjoerling

Sven A. Gejer

Ernst De Magnusson

Erik Halvar Nordenmark

Thomas E. Oevergaard

Captain John Olaf Pettersson,
Marine Superintendent, Swedish American Line, Brostrom Lines

UNION OF SOUTH AFRICA

<u>Delegates</u> M. W. Manson,
Chief of Communications Action, South African Railways

Dr. E. Percy Phillips,
Head, Scientific Liaison Office,
Washington, D. C.

UNION OF SOVIET SOCIALIST REPUBLICS

<u>Delegates</u> A. V. Dubinin,
Chief, Communications Group, Soviet Government Purchasing Commission

A. A. Raev,
Engineer, Soviet Government Purchasing Commission

UNION OF SOVIET SOCIALIST REPUBLICS (continued)

Commander K. P. Ryzhkov, U.S.S.R. Navy,
Representative of the Hydrographic Service of the U.S.S.R.

UNITED KINGDOM

<u>Leader</u>	Sir Robert Watson-Watt, C.B., F.R.S., Ministry of Transport
<u>Deputy Leader</u>	Denis O'Neill, Ministry of Transport
<u>Delegates</u>	Group Captain E. Fennessy, O.B.E., Radio Industry Group
	C. E. Horton, Admiralty
	Captain F. O. Madden, Shipping Industry
	Lieutenant R. B. Michell, D.S.C., R.N., Admiralty
	Colonel B. S. Millard, T.D., D.L., Shipping Industry
	Captain T. L. Owen, O.B.E., R.D., Trinity House
	Commander Gilbert V. Parmiter, R.N., Admiralty
	L. H. J. Phillips, Radio Industry Group
	Captain R. W. Ravenhill, C.B.E., D.S.C., R.N., Admiralty
	Captain D. F. Robinson, C.B., R.D., Shipping Industry
	William Ross, Ministry of Transport

UNITED KINGDOM (continued)

H. Stanesby,
General Postoffice

Captain J. C. Taylor,
Ministry of Transport

Dr. G. Touch,
Ministry of Supply

<u>Adviser</u> Captain W. H. Coombs,
Ministry of Transport

<u>Secretary</u> W. F. Palmer,
Ministry of Transport

<u>Observers</u> D. H. Sadler,
Admiralty

Captain A. V. S. Yates,
Radio Industry

UNITED STATES

<u>Chairman</u> John S. Cross,
Assistant Chief, Telecommunications Division,
Department of State

<u>Vice Chairman</u> Edward M. Webster,
Commissioner, Federal Communications Commission

<u>Delegates</u> Clarence A. Burmister,
Lieutenant Commander, Coast and Geodetic Survey,
Department of Commerce

P. DeForrest McKeel,
Civil Aeronautics Administration, Department of
Commerce

Daniel J. McKenzie,
Master Mariner, Transportation Corps, War
Department

G. Gordon McLintock,
Commodore, United States Maritime Service,
United States Maritime Commission

Irvin L. McNally,
Lieutenant Commander, United States Navy

H. C. Moore,
Captain, United States Coast Guard

Edward C. Phillips,
National Federation of American Shipping, Inc.,
Washington, D. C.

Congressional Advisers

Herbert C. Bonner,
House of Representatives*

Fred Bradley,
House of Representatives

Willis W. Bradley,
House of Representatives*

John C. Brophy,
House of Representatives

Horace Seely Brown,
House of Representatives

T. Millet Hand,
House of Representatives*

Henry M. Jackson,
House of Representatives*

Eugene J. Keogh,
House of Representatives*

Cecil R. King,
House of Representatives*

Henry J. Latham,
House of Representatives

Robert Nodar, Jr.,
House of Representatives*

* Did not attend.

UNITED STATES (continued)

David M. Potts,
House of Representatives

Emory H. Price,
House of Representatives*

Leo F. Rayfiel,
House of Representatives*

Thor C. Tollefson,
House of Representatives*

Alvin F. Weichel,
House of Representatives

Special Assistants to Congressional Advisers

Marvin Coles,
Chief Counsel, Merchant Marine and Fisheries Committee, House of Representatives

Guy H. LaBounty,
Chief Investigator, Merchant Marine and Fisheries Committee, House of Representatives

Industry Advisers**

American Telephone and Telegraph Company

Francis M. Ryan

Bendix Aviation Corporation

Paul Kreager
Haig Kafafian (Alternate)

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* Did not attend.

** In addition to the industry representatives, technicians and/or observers of the following companies participated in the IMMRAN:

American Merchant Marine Institutes, Inc.
Arlington Electric Products, Inc.
Bell Telephone Laboratories
Bendix International
Eastern Industrial Company (Continued)

UNITED STATES (continued)

Bludworth Marine

Willard C. Blaisdell

Fairchild Camera and Instrument Corporation

George J. Podeyn, Jr.
H. E. Hale (Alternate)

Hazeltine Electronics Corporation

W. H. Wilson

International General Electric Company

C. G. Roberts
Frank H. Speir (Alternate)

Lake Carriers' Association

C. M. Jansky (Speaker)

Mackay Radio and Telegraph Company, Inc.

E. H. Price

EDO Aircraft
Furness Line
General Precision Laboratories
Glaveston Distributors
International Standard Electric
International Telephone and Telegraph
Lawton Products Co., Inc.
Maritime Association of the Port of New York
Moore-McCormack Lines
Pacific-American Steamship Association
Philco Corporation
Radio Navigational Instruments Corporation
Radiomarine Corporation of America
Southern New England Telephone Co.
Tropical Radio Corporation
Western Electric Company, Inc.
Westinghouse Electric Corporation

National Federation of American Shipping, Inc.

American Merchant Marine Institute, Inc.

H. W. Schlichting (Adviser to United States delegate from NFAS)

Pacific American Steamship Association

A. C. Morrison (Adviser to United States delegate from NFAS)

Radio Corporation of America

Thomas A. Consalvi
C. A. Magnell (Alternate)

Sperry Gyroscope Company, Inc.

Eric I. Isbister

Submarine Signal Company

Kenneth V. Curtis

Sylvania Electric Products, Inc.

A. C. Viebranz

Wallace & Tiernan Products, Inc.

Warren F. Haring

Government Advisers

United States Coast Guard

Lawrence M. Harding,
Captain, USCG

George E. Howarth,
Lieutenant Commander, USCG

G. L. Ottinger,
Lieutenant Commander, USCG

Navy Department

Frank Virden,
Captain, USN

G. F. Kennedy,
Commander, USNR, Hydrographic Office

Sue Chamberlin King,
Lieutenant, W(A) USNR

Alfred H. Kerrick,
Hydrographic Office

Gunnar Liefson,
Hydrographic Office

Alton B. Moody,
Hydrographic Office

Henrietta H. Swope,
Hydrographic Office

William G. Watt,
Hydrographic Office

United States Coast and Geodetic Survey

Casper M. Durgin,
Commander, USCGS

Harold R. Edmonston

Gordon B. Littlepage, Jr.

Civil Aeronautics Administration

Richard Battle

Peter Caporale

Raymond E. McCormick

Federal Communications Commission

John R. Evans

UNITED STATES (continued)

Charles C. Kolster

William N. Krebs

Howard C. Looney

William F. Minners

Lester W. Spillane

<u>United States Maritime Commission</u>

Gilbert C. Fonda,
Lieutenant Commander, United States Maritime Service

John L. Thompson,
Lieutenant, United States Maritime Service

Alan Osbourne

<u>War Department</u>

Richard T. Black,
Lieutenant Colonel, Air Corps

Max W. Hall,
Lieutenant Colonel

URUGUAY

<u>Delegate</u> Lieutenant Commander Enrique Real De Azua,
Uruguayan Navy

VENEZUELA

<u>Delegates</u> Lieutenant Antonio Jose Alfonzo,
Armed Forces of Venezuela

Pedro Elias Behrens,
Radio Technician

Renato Gutierrez,
Telecommunications Director, Venezuelan Communications Ministry

YUGOSLAVIA

Delegates

Captain Anton Aksic,
Yugoslavian Ministry of Shipping

Theodore Tijan,
Merchant Marine Attache to the Embassy of Yugoslavia,
Washington, D. C.

INTERNATIONAL SECRETARIAT

Honorary Chairman

Garrison Norton,
Assistant Secretary of State

Chairman

Dr. William L. Everitt,
University of Illinois

Executive Secretary

John S. Cross,
Assistant Chief, Telecommunications Division, Department of State

Special Assistant to Executive Secretary

Donald R. MacQuivey,
Telecommunications Division, Department of State

Press Relations Officer

Joseph W. Reap,
Office of the Special Assistant for Press Relations, Department of State

Protocol Officer

Raymond B. Muir,
Division of Protocol, Department of State

Program Coordinator

L. E. Brunner,
Lieutenant Commander, United States Coast Guard

Executive Officer

Henry F. Nichol,
Division of International Conferences, Department of State

Special Assistant to Executive Officer

Dorothy King,
Division of International Conferences, Department of State

Liaison Officers

J. G. Bastow,
Lieutenant, United States Coast Guard

D. G. Cowie,
Lieutenant, United States Coast Guard

A. H. Graham,
Lieutenant, United States Coast Guard

C. L. Olson,
Lieutenant, United States Coast Guard

D. R. Domke,
Lieutenant (jg), United States Coast Guard

C. R. Newton,
Lieutenant (jg), United States Coast Guard

Documents Officer

Mary Haslacker,
Division of International Conferences, Department of State

Assistant Documents Officer

Leonore Hemelt,
Division of Organization and Budget, Department of State

Administrative Officer

Reginald T. Johnson,
Division of International Conferences, Department of State

Finance Officer

John R. Wheeler,
Division of International Conferences, Department of State

Transportation Officer

Leonard Brody,
Division of Central Services, Department of State

Registration, Housing, and Information Officer

Florence H. De Gonzalez,
Division of International Conferences, Department of State

Assistant Registration, Housing, and Information Officer

Mary Alice Sheridan,
Division of International Conferences, Department of State

Presentation Officer

Stuart I. Freeman,
Division of Central Services, Department of State

Supply and Order of the Day Officer

William D. Misfeldt,
Division of International Conferences, Department of State

Reporting Services

Helen Campbell
Eleanor Koontz
Edna Moyer
Violet Voce

Stenographic Services

Ellen Hyry,
Supervisor

Juanita Ames
Isabell E. Erzen

INTERNATIONAL SECRETARIAT (continued)

Rose Hahlen
Donna Huskey
Mary S. Kilburg
Norma Jean Main
Gladys Vance
Doris Williams